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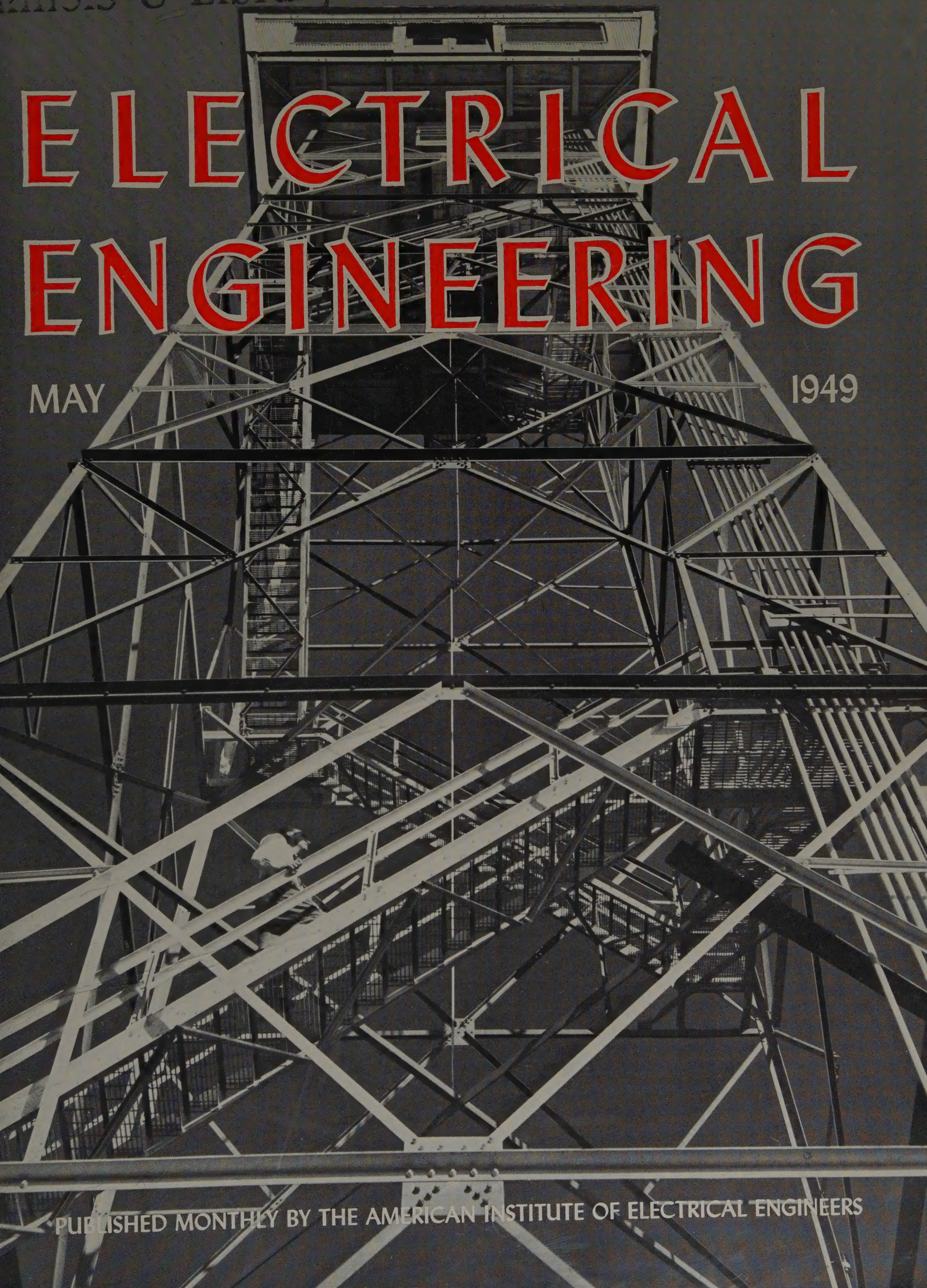

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Engineering—An Invisible Export

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By exporting large quantities of electric equipment, the electrical industry of the United States is making a definite contribution to world recovery. However, an even greater contribution can be made and indeed is being made, through the export of an intangible commodity, "American engineering know-how." This type of international co-operation functions through license and technical assistance agreements between American and foreign firms.

THE PRESENT STATE of world affairs has convinced most Americans that international boundaries cannot insulate one part of the world from another. It is becoming an accepted fact that human want, wherever it exists, is a highly inflammatory condition threatening our own peace and security. With the destiny of Americans tied up so directly with international economic conditions, it may be interesting for electrical engineers to consider briefly one of the lesser-known ways in which their efforts are genuinely contributing to the improvement of such conditions.

It is generally known that large quantities of electric equipment have been exported from the United States during the postwar period and, to the extent that these exports constitute capital equipment, they represent a definite contribution by the American electrical industry to world recovery. It has become obvious, however, that United States exports alone are not a complete solution to the intricate problems of international economics with which so many countries are confronted today. This is true primarily because United States exporters must be paid in United States dollars, and so long as the United States mint maintains a monopoly on the production of dollars, foreign purchasers of our goods must obtain United States currency or credit through sales of their own goods or services to Americans. The flow of trade between two countries might be likened to the flow of current in an electric circuit with the total value of goods going into each country being equal to that flowing back in the reverse direction. In practice, this equation is complicated by international loans, the sale of such intangibles as shipping and insurance, and also by transactions involving three or more countries, but in the long run the equality is inexorable and must be satisfied. It becomes clear, therefore, that something in addition to a high level of United States exports is necessary for world stability. Among other things, the productive capacity of foreign countries must be stepped up to increase the local supply of goods and also so that each country's exports can be made to balance the volume of imports desirable or even necessary for its national welfare.

It may come as a surprise to some electrical engineers to discover that the electrical industry of the United States has pioneered in a form of international co-operation which strengthens foreign industries without imposing strain on our own economy, which contributes to most of the objectives of the Marshall Plan without cost to the American taxpayer, and which is in keeping with the principles of free enterprise.

This form of international mutual assistance functions through license and technical assistance agreements between American and foreign manufacturers.

COMMERCIAL SETTING OF LICENSE AGREEMENTS

In order to understand the background of these licensing activities, it is necessary to give consideration to the trends of foreign governments toward import restrictions and foreign-currency controls which have become epidemic in recent years. These restrictive measures have been dictated partly by the practical necessity of directing dwindling dollar reserves into the purchase of essential goods, but there are additional deeper rooted motives. The nations of the world all desire home industries, not only to expand local employment and purchasing power, but also to escape dependency upon foreign countries for those manufactured goods which are vital to their national existence.

Two world wars in 25 years, with their attendant blocking of international trade channels, have forced these countries to set up manufacturing plants to supply their vital needs, and, during times of peace, to protect those plants from foreign competition with import restrictions of various kinds. While these restrictive policies may be ill-advised from the standpoint of broad economic theory, they must be viewed with some degree of tolerance by anyone familiar with the history of our own country's tariff policy and they are, in any event, a stark reality in today's international picture. These factors already have had an effect on international trade and they probably will have an even greater influence in the future. Many countries which were previously good markets for American electrical goods are now tightly closed, and each United States manufacturer is faced with the alternative of accepting the curtailment of his world markets or of discovering new ways of participating in them.

There are several courses which have been followed by United States firms. One possibility is the erection of factories or assembly plants in the individual foreign countries and under American management and ownership. An alternative method of entering such markets is

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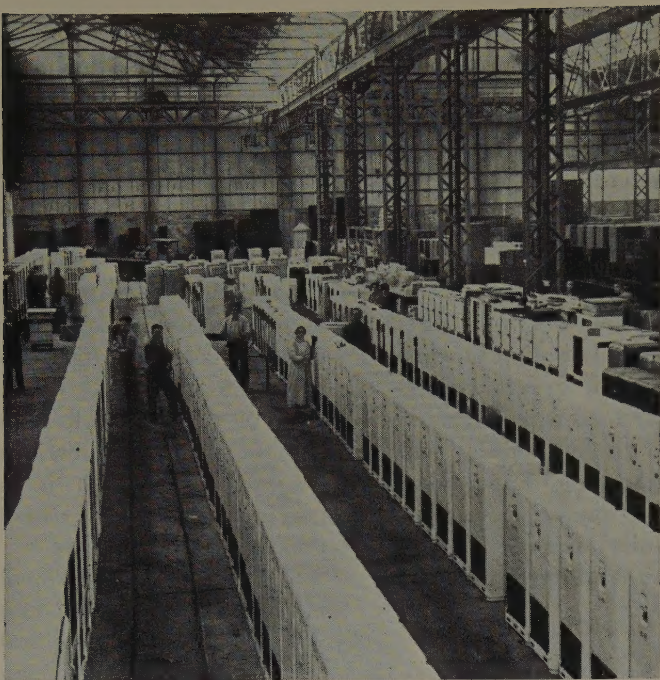

Figure 1. Household refrigerators being manufactured to American designs and under American license in Argentina

through joint ownership of factories with local individuals and financial interests. Both of these methods involve the investment of large sums of money in foreign countries and entail, in some instances, considerable risks from war, revolution, and hostile legislation. Many American manufacturers are not in a position to undertake the expenditures and risks or to supply the personnel which such foreign manufacturing operations require.

Still another course, perhaps open to a larger number of American concerns, is to be found in license agreements which involve greatly reduced investment risks, but which can bring a reasonable return to the American licensor even from those countries which are most inaccessible to American-made goods.

WHAT THE AGREEMENTS COVER

Foreign licensing may take many forms and the contracts themselves are subject to countless variations. In general, however, the American manufacturer grants licenses under his foreign patents and also makes available to the foreign licensee complete design data and shop information necessary for the manufacture of apparatus covered by the license agreement including drawings, material and process specifications, inspection and test procedures, and the like. When an agreement is being considered in a country having electrical manufacturing firms already in existence, it usually is found advantageous to enter into a contract with an established company, preferably one which manufactures kindred lines of apparatus, so as to make use of existing equipment and personnel. When no established manufacturer is to be found, it may be practical to enter into an agreement calling for the planning, construction, equipping, and operation of a completely new plant. Contracts involving this type of enterprise may become exceedingly broad in scope, and in all instances will include a sizable educational program designed to train engineering and supervisory personnel to carry on the operation of the new factory when production begins.

The agreements, therefore, may be seen to provide the foreign manufacturer with reliable "de-bugged" designs in return for an initial down payment and a small royalty payable on each piece of licensed apparatus sold by the foreign manufacturer. Many times a foreign manufacturer will find it expedient to station one or more of his engineers in the plant of the American licensor to observe the manufacturing operations at first hand and to keep abreast of the latest technical advances in design or manufacturing methods.

Sometimes, American designs must be modified to meet conditions existing in a licensee's home market. These design modifications will be based upon such factors as the availability of raw materials, climatic conditions, and differences in altitude, voltage, and frequency, and normally will be found to lie within the capabilities of the foreign licensee's own engineering staff. In unusual cases, special engineering services may be required of the American associate which can be covered by a special provision in the original agreement, or contracted for as the need arises.

In addition to providing patent rights, designs, personnel training, and special engineering service, a license and technical assistance agreement with American manufacturers has another less tangible but equally desirable feature from the standpoint of the foreign licensee. Such an agreement provides him with a technical listening post within the United States where a large fraction of the world's technical research is being carried on today. The foreign licensee thus is assured of an opportunity to keep up to date on the latest scientific and engineering trends, not only in those fields covered by the license agreement, but in others as well.

SALES OF COMPONENT PARTS

Many times it is found that the foreign licensee's volume of production makes impractical the expensive tooling required for low unit-cost production of certain component parts and subassemblies. In cases of this sort, the foreign associate may find it advantageous to purchase these components from the American licensor and to import them for incorporation into his own finished product. This practice of "plugging in" to the American company's assembly lines may simplify the licensee's manufacturing and tooling problems greatly, and reduce his required capital investment. Simultaneously, it would be building up high-volume production for certain of the American company's tools and automatic machines, thereby accelerating the amortization of expensive equipment and fixtures in which the American company has invested large sums.

Consider, for example, a licensee about to engage in the manufacture of electric household refrigerators. In the beginning such a licensee probably will find it advisable to purchase the complete compressor units and evaporators from the American associate and to assemble this unit into a cabinet produced in his own plant. As time goes on, the licensee logically might undertake the manufacture of the compressor units himself, on a small scale at first, gradually

expanding his production as he acquires additional equipment and experience. In this hypothetical case one component which the foreign licensee might not find advisable to manufacture himself would be the thermostatic control unit. He well might discover that with his volume of production it would be advantageous to continue to buy these components year after year rather than to undertake this delicate manufacturing operation, especially in view of the very favorable price which the American associate could offer because of his tremendous volume and the fact that the American concern's investment in tools and quality control equipment already has been made. This hypothetical case illustrates the manner in which the foreign licensee and the American concern may co-ordinate their activities to bring about the most mutually profitable division of effort.

BENEFITS OF LICENSING

From the foreign licensee's viewpoint, the great advantage of entering into a license agreement is the fact that for a relatively small initial sum, and a reasonable royalty per unit manufactured and sold, he can avoid the long delay and expense of a research and development program of his own. Moreover, the chances are that his expected volume of production would not be such as to justify development and research on a scale comparable to that carried out in the United States. The development cost thus saved can be put into capital equipment and raw materials, thereby increasing the foreign licensee's production and turnover. An association of this sort also can be expected to stimulate the foreign concern's own engineering staff because of the exchange of ideas and information with the engineers of the American licensor.

It should be understood that the United States has no monopoly on engineering talent; competent scientists and engineers can be found in every quarter of the globe. The commodity which American firms are in a unique position to sell is the fruit of large, integrated research and development programs which can be carried out in the United States primarily because of a gigantic home market and the vast volume of production which it can absorb.

The most significant advantage to an American firm of a foreign licensing program is the fact that it enables that firm to participate in foreign markets in spite of exchange controls, import quotas, tariffs, and the like which have been set up by a large majority of foreign countries. Foreign governments, if fully informed regarding the benefits of these agreements, have been found to be very sympathetic toward the granting of dollar exchange for service fees and royalties. Also, the royalties which an American firm receives from a foreign license agreement represent a very "efficient" means of participating in that foreign market because of the absence of such usual sales expenses as advertising and sales promotion, field servicing, and collection losses. Thus, an American firm facing the loss of a market in a particular country should compare the probable royalty yield of a license agreement with the net profit, instead of the gross sales, previously made in that country. A license agreement also would avoid the depletion of American stock piles of scarce raw materials and would reduce drastically the drain on the foreign country's dollar reserve thereby affording such funds for other international transactions.

Other benefits to American licensors will depend upon individual circumstances, but in almost all instances the foreign license will enable the United States manufacturer to amortize the cost of his research and development programs over a considerably larger volume of business. This in turn may make possible the plowing back of additional funds into research and development. A foreign licensing program can be used also to build up a substantial component parts business, which may be extremely desirable to some American manufacturers, and the foreign licensee can profit from the American associate's large volume of production. In addition, it is almost always true that import restrictions and tariffs are much less on component parts and subassemblies than on finished apparatus. A further benefit to American licensors is the fact that a vigorous, progressive, and respected licensee in a foreign country inevitably will create good will and a wider acceptance within that country of American engineering practices and standards, thereby paving the way for increased sales of such American electric apparatus as cannot be manufactured within the country itself. The foreign licensee's handling of various products made by the American associate also will keep the latter's name and trade-mark before the public.

Figure 2. The main isle of the Hengelo, Netherlands, works of the Heemaf Company, licensee of the Westinghouse International Company, which builds electric transportation equipment and industrial motors and accessories

ARGUMENTS AGAINST FOREIGN LICENSING

It is only fair to state that there are some, especially among those favoring isolationist policies, who are opposed to foreign licensing. The majority of these opponents to foreign licensing programs are victims of the fear that competitors are being built up within foreign countries who will undermine American foreign trade and, as the argument goes, cause depression and unemployment of American workers. Another charge which has been levelled at foreign licensing activities generally is that they give rise to "cartels." It is not always entirely clear what those who use this term mean but, presumably, the word properly has reference to price fixing, division of territories, restriction of production, and general restraint of trade and competition. It has been argued also that the granting of foreign licenses will encourage foreign governments to control and restrict their imports to an even greater extent and will result ultimately in such national compartmentalization of trade as completely to disrupt international commerce.

A complete answer to these charges would involve a lengthy analysis of foreign trade data and statistics and cannot be given an exhaustive presentation here. It should be borne in mind, however, that while foreign licensing programs undoubtedly do alter the patterns of world trade, there are few informed observers who would argue that today's pattern is satisfactory. Some may ask how we can expect to continue to sell machinery to Brazil if, with our assistance, they will have their own machine industry a few years from now. The answer is that perhaps we will not, but we will sell (and they will be able to buy from us) many other things. A century ago, Europe sold us most of our machinery and a large part of our manufactured goods. This is no longer true because we have become the largest manufacturing country in the world. Nevertheless, the value of Europe's exports to the United States is now greater than ever before and the standard of living of Europe's workers, despite the chaotic conditions resulting from war, is still higher than in the previous century. As a matter of fact, there is abundant evidence that the relatively well-industrialized countries have been our best customers. For example, we sell far more to Canada than to China. Moreover, foreign industrialization will take place with or without our help, for the widespread desire for home industry and self-sufficiency is deep seated and not to be denied. It hardly seems consistent with American traditions to lock the door on our technical resources and attempt to maintain our present industrial pre-eminence by preventing the growth of competition rather than by relying upon our ingenuity and inventiveness to keep us ahead of competitors abroad.

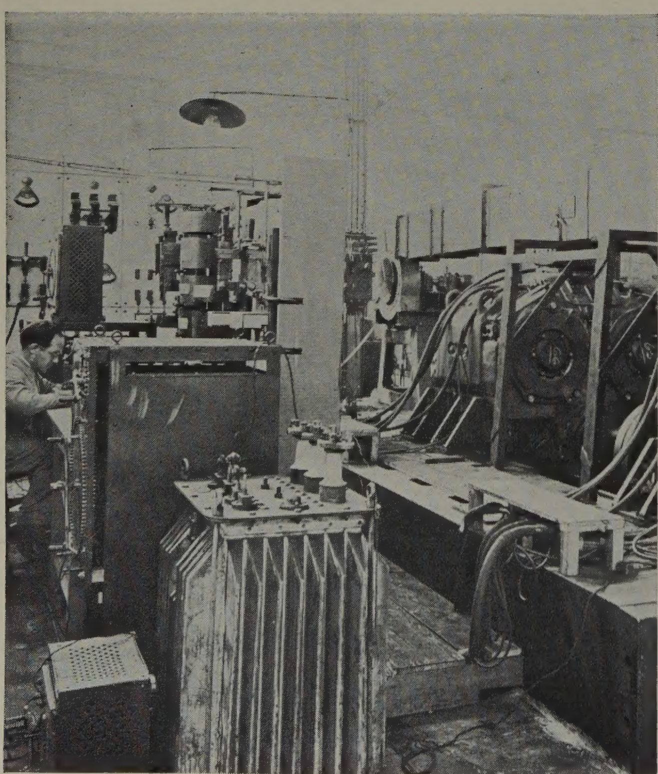

Figure 3. Traction motors, built with the aid of Westinghouse research and manufacturing techniques, undergoing tests in the Champagne plant of the French company, Le Materiel Electrique

Foreign licensing should not be condemned on the grounds that it engenders international cartels or combinations in restraint of trade. License agreements, like any other contracts, may be used for this purpose, but the restraint of trade is by no means inherent in foreign licensing activities. Actually, the agreements with which the writer is familiar do not in any way fix prices but, on the contrary, give very broad sales rights under foreign patents and, in practice, promote rather than restrict competition.

It seems out of keeping with the present condition of world affairs, when we are spending billions of dollars for foreign reconstruction, to refuse to supply some of the knowledge that will put those dollars to lasting use. To make available the tools and knowledge for self-help seems to be one of the most enlightened forms of assistance that can be given to the rest of the world. Also, the very intimate relationship which foreign licenses engender between citizens of the United States and citizens of foreign countries constitutes an invaluable channel through which to spread the truth about America and the free enterprise system. No one would argue that foreign licensing is suitable for adoption by every manufacturer or by a single manufacturer in every country, but for a period of more than 25 years it has proved itself a valuable supplement to conventional exporting, and in the present international situation it would appear capable of making a substantial contribution to international prosperity, stability, and good will.

In the words of W. E. Knox, president of the Westinghouse Electric International Company:

> . . . two World Wars with the resultant destruction of wealth producing facilities, have impoverished the world. We cannot do business with a poorhouse. We must take action which will raise the levels of production the world over.
>
> In other words, we must foster the industrialization and use of machinery in foreign countries to advance their prosperity to a point where they will have something left over with which to buy our goods, or to exchange with us, for our goods.
>
> We would like to see the people of the world provided with the fundamentally required tools and "know-how" so that all people of the earth may, through work, production, and distribution, have enough to eat, good health, suitable clothes to wear, adequate housing, and, generally, make the best of this all-too-short stay on earth.

Distribution-Transformer Voltage Stresses

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INFREQUENT REPORTS of severe mechanical damage to small transformers as a result of nearby lightning strokes have led to the conclusion that the cause of the damage was the passage of heavy lightning currents in opposing directions in the two halves of the low-voltage windings. These cases have been rare but are of considerable interest as they have led to the consideration of the effects of the more frequent lightning currents of smaller magnitude flowing in distribution-transformer low-voltage windings.

Laboratory studies made with a high-current impulse generator have demonstrated that distribution-transformer high-voltage windings may be subjected to damaging voltage stresses as a result of impulses applied to the low-voltage windings. Investigations of different winding arrangements and of different connections of the transformer terminals have helped understanding the problem. Flux plots have been made and internal oscillations studied. The most important result of this work is the discovery that destructive voltages may appear within a high-voltage winding, due to lightning currents in the low-voltage windings, even though its terminals are both solidly grounded or protected by efficient primary lightning arresters. Although some control is available by modification of transformer design, it does not appear to be practical or economical to effect an over-all solution to the problem in this way.

Field studies on a rural distribution system have been made by the use of surge crest ammeter links installed on every conductor emanating from the transformer locations under study. The results as shown in Figure 1 indicate that the number and severity of the surge currents arriving at the transformers by way of the secondary leads or pole grounds were nearly as great as for those arriving by way of the primary leads. Figure 2 illustrates the current distribution when typical surges arrive over secondary leads.

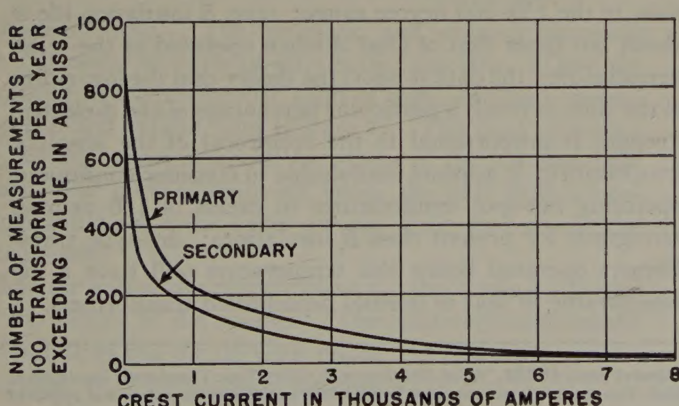

Figure 1. Relative number and severity of measured surge currents on primary and secondary conductors at distribution-transformer locations

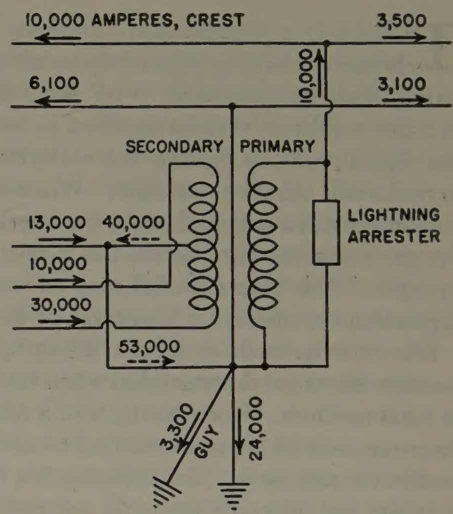

Figure 2. Distribution of surge currents at a distribution-transformer location, surge arriving by way of secondary service conductors

From laboratory and field experience, it becomes evident that the best lightning protection to distribution transformers would be afforded by applying suitable arresters to the secondary terminals as well as to the primary terminals. Small inexpensive secondary arresters are available which are capable of discharging a 5 by 10 microsecond impulse current of 65,000 amperes.

Field experience has been gained over a 3-year period on two similar groups of distribution-transformer installations. Both groups were located on the same distribution system and, as far as could be determined, had the same degree of lightning exposure. The group which had secondary arresters in addition to the usual primary arresters showed a marked reduction in failure rate as compared to the other group with primary arresters only.

To summarize:

1. Laboratory tests show that lightning currents entering distribution transformers through the low-voltage secondary terminals can cause damaging voltages in the primary windings.

2. Lightning arresters connected to the primary terminals are generally ineffective in protecting the primary windings against voltages produced by lightning currents entering the transformer by way of the low-voltage secondary terminals.

3. Comparative field tests on transformers with and without secondary arresters, in addition to the usual primary arresters, showed that the secondary arresters reduced the transformer failure rate to less than one-quarter the rate without secondary arresters.

4. Installation of secondary arresters at distribution-transformer locations is economical where secondary exposure is high or where a greater degree of continuity of service is desired.

Digest of paper **48-292**, "Voltage Stresses in Distribution Transformers Due to Lightning Stresses in Low-Voltage Circuits," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Aging of Dry-Type Transformer Insulation

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THERE IS a fundamental difference in the life of insulation containing organic material operated in an insulating liquid as contrasted to the same insulation operated in a gas medium. When operated in an insulating liquid, the liquid tends to replace the material deteriorated and so maintains electrical strength. When operated at a high temperature in a gas medium, as the deterioration progresses, the gas replacing the varnish has a much lower dielectric strength. The base material may or may not deteriorate depending on whether it is organic or inorganic.

Life criteria, such as tensile strength, thus may fail to measure electrical deterioration when insulation is operated in a gas medium. Recognizing this, a new criterion for the determination of life of insulations when operated in a gas medium is proposed. This criterion is a certain percentage of initial hot dielectric strength, the end of life being considered to be reached when the hot dielectric strength has decreased to this value.

Insulations, such as asbestos, fiber-glass yarn, kraft paper, and black varnished cambric, were investigated, each being impregnated with a varnish. These insulations were operated in air at atmospheric pressure at various temperatures and dielectric tests periodically applied with insulation at operating temperature. The end of insulation life is assumed when this dielectric strength has decreased to one-half of its initial value. The extent and consistency of these data for one material are illustrated in Figure 1 and a summary of data to date in Figure 2. These data are well represented by straight lines when plotted against reciprocal absolute temperature scale on semilog paper as proposed by Dakin. Some data on insulations operated in inert atmosphere indicate a life at least three times as long, or a possibility of operation at 25 degrees centigrade higher temperature than when operated in free air.

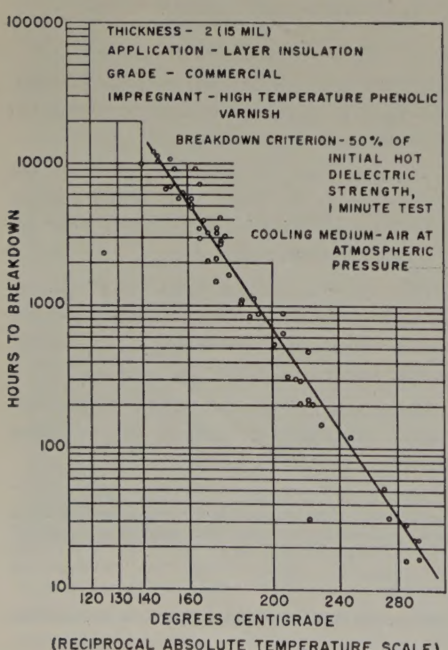

Figure 1. Life characteristic — asbestos sheets

Results and conclusions from this investigation show that in a gas medium: the dielectric strength of class *B* insulation is reduced to one-half its initial value when operated continuously for three to four and one-half years at 130 degrees centigrade; it is similarly reduced for class *A*, when operated at 105 degrees centigrade for two years; the degrees increase in temperature required to reduce insulation life 50 per cent is ten degrees centigrade for class *A*, operated in the 105–150 degree centigrade range, and 13 degrees for class *B* materials, in the 130–200 degree range; class *B* insulation life is about ten times that of class *A* when operated at the same temperature; the data support the theory that the logarithm of the time to reach a particular percentage of the dielectric strength is proportional to the reciprocal of the absolute temperature; it appears inadvisable to consider continuous operating hot-spot temperatures in excess of 130 degrees centigrade for present class *B* insulations; dry-type transformers operated below this temperature will have a life comparable to that of normal liquid-filled transformers.

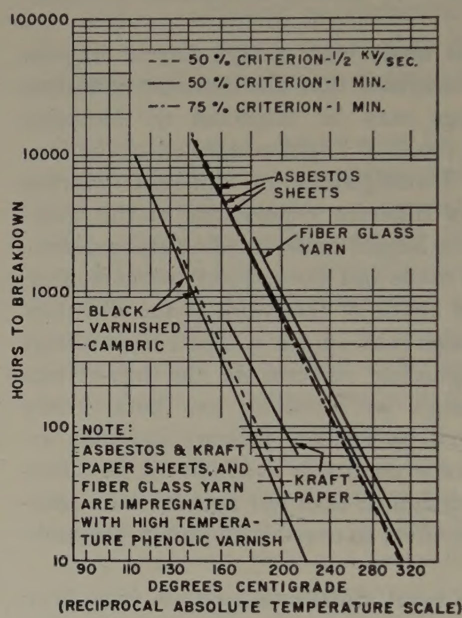

Figure 2. Summary of life characteristics of insulations in air at atmospheric pressure

Digest of paper **48-289**, "Aging Characteristics of Dry-Type Transformer Insulation at High Temperature," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Vaporization Cooling of Electric Machines

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This method of cooling is as revolutionary as hydrogen cooling was in the twenties. This article describes the fundamentals of vaporization cooling, the electric machines with this cooling, and the effect of the coolant upon the insulation and other interior parts.

THE EFFECTIVENESS of the removal of the waste products of a body determines its producing power. In electric machines the coolant and its application are therefore of primary importance. With vaporization cooling the waste product—heat—is removed by the coolant passing from the fluid state into the vapor state.

Vaporization cooling makes a standard universal solution feasible for the cooling of large machines of all types. Water is supplied in mist form to the natural surfaces bordering the air gap. The gap and the space surrounding the end windings are kept under vacuum. Compared with air cooling, the heat transfer coefficient is at least 50 times as great. At full load, 1/80 of the weight and two-fifths to one-fifth of the gaseous volume are needed; less is needed at part-loads. This gives an indication of the potency of the coolant.

The fundamentals of vaporization cooling to be discussed in the first part of the article prove in short that

1. The heat losses are removed as evenly as they are generated.
2. Air vents, which made up 4 to 12 per cent of the core length, are no longer needed. The resulting solid stator core is explosionproof and corrosionproof.
3. The stator core circumference becomes the outside of the machine.
4. Cooling fluid can be applied in accordance with the need. The vapor has a small surface friction. Both are explosionproof, unburnable, and will remove any kind of dust and undesirable substances fully.
5. Fans and gas filters become superfluous. The coolers required for closed circuit cooling become considerably smaller. Auxiliary apparatus hardly is needed. Most of it is simple and fully developed.
6. Compared with hydrogen cooling, vaporization cooling eliminates heavy housing, purifying equipment, and shaft sealing devices.

FUNDAMENTALS OF VAPORIZATION COOLING

Basic Principles. The magnetic and winding materials are the essential parts of an electric machine. They are arranged in five concentric rings of iron, iron and copper, air, iron and copper, iron (Figure 1). The rings adjoining the air gap generate about four-fifths of the full-load heat losses. For cores without air vents, the heat field is two-dimensional since the losses are the same throughout the core length.

The air gap is the critical place for the cooling and also for the supply of the coolant. The relatively unprotected end windings can use up what remains of its cooling power. The basic heat-transmission formula is

$$1/U = \Sigma b/K + \Sigma 1/h$$

where U is the over-all heat-transmission coefficient, Σ the sum of the individual values, b the wall thickness in feet, K the heat conductivity coefficient, and h the heat-transfer coefficient. K in Btu per square foot per foot per hour per degree Fahrenheit is for copper 224, aluminum 118, iron 35, iron laminations (air gap) 25–15, laminations (air vents) 1–0.4, insulating materials 0.3–0.15, trapped air in slots 0.025. h in Btu per square foot per hour per degree Fahrenheit is for air 25–15, hydrogen 40–25, at the most favorable cooling speeds and atmospheric pressure.

These figures bring out the bottle necks of the cooling (air, insulation thickness). The increase of the tooth temperature with the distance from the air gap keeps the core at an elevated temperature and makes the natural cooling of the stator-core outer circumference more effective. For thick cores and great winding heights, the air gap cooling can be supplemented by means to be discussed later.

A maximum rise in air temperature of about 20–30 degrees centigrade is permissible. Fans and circuit resistance can reduce this temperature span up to 8 degrees centigrade. The maximum temperature rise for the windings is 55 degrees centigrade (class A insulation). The temperature rise of the air is also a serious disadvantage. Moreover, an even air circulation cannot be guaranteed with air vents in the cores. The mean over temperature therefore is taken at seven-tenths to eight-tenths instead of one-half of the maximum temperature rise. All this makes the temperature anywhere in the air-cooled machine guesswork.

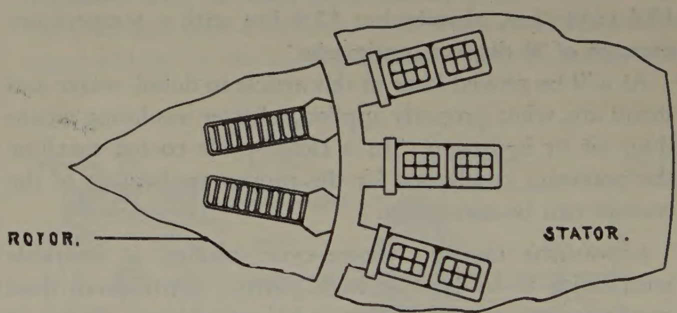

Figure 1. The concentric rings

Full text of paper **49-49**, "Vaporization Cooling of Large Electric Machines," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *TRANSACTIONS*.

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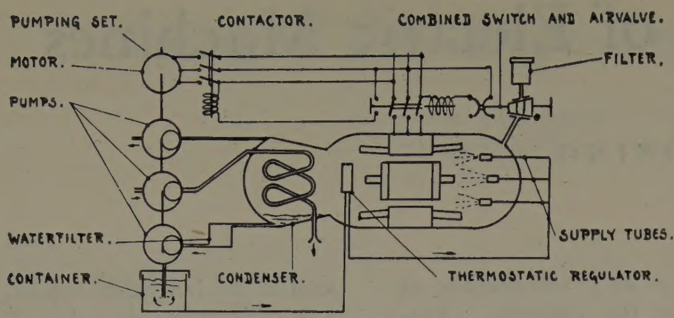


Figure 2. The cooling scheme in principle

Constant Coolant Temperature. With constant cooling medium temperature, the insulation stresses over the core length will be equal. A sizable decrease in necessary surface or in insulation strain is the result. In an evaporating medium the temperature remains constant until the medium is vaporized fully. Since this holds at constant pressure only, the cooling temperature can be adjusted.

The cooling being limited to the air gap, the cooling fluid is utilized equally and fully; for there are no dead corners, plugged passages, or air vents. Vapor and fluid form a fog due to the high rotor surface speed. A housing becomes superfluous. The end shields are small, sturdy, and light. Vacuum pressures are desirable because of the surface friction. For water at 0.8 pound per square inch absolute, vaporization temperature 34.2 degrees centigrade, one pound has a volume of 418 cubic feet and absorbs 979.6 Btu. At 1.6 pounds per square inch absolute, temperature 47.3 degrees centigrade, it has a volume of 214 cubic feet and absorbs 962.5 Btu. One pound of air, about 13.6 cubic feet, absorbs but 12.9 Btu with a temperature increase of 30 degrees centigrade.

As will be proved later in this article in detail, water and steam are, when properly applied, a better insulating means than air or hydrogen. In a closed-cycle cooled machine the necessary conditions for the proper application of the coolant can be met easily.

Closed-Cycle Cooling. Closed-cycle cooling is desirable with fluids to be kept at high purity. Only small fluid quantities are needed. The end rings and end shields fit closely over the end windings. The vapor space therefore will be small and highly utilized. Note that the various heat transfer coefficients are: water 400–1,200, vaporizing water or condensing steam 2,000 and more, air 15–25, hydrogen 25–50. Thus even an overdimensioned condenser in this system will be much smaller than the cooler of a hydrogen-cooled machine.

During condensation, air and all other undesirables are instantly removed; another advantage over hydrogen cooling. Moreover, a fluid can be cleaned much better than can a gas. Dust from any source (atmosphere, brushes, collectors, commutators) is removed as sludge by the fluid filter. The vapor flow cleans the interior of the machine progressively. Neither scavengers nor long drying-out periods are needed. Air filters and fans are eliminated. Any reason for not having the exciter in the main housing disappears, so that one of the shaft seals is not necessary.

The use of hydrogen makes complicated auxiliary equipment and skilled attendants necessary. With an evaporating fluid, only easily maintained standard equipment is needed, used in part for all the machines of a set. Generator fires are unlikely with hydrogen, impossible with water vapor. Neither ozone nor nitrous oxides can be found in hydrogen-cooled or vaporization-cooled machines. Corona does not do damage. Since one pound of water requires 5,720 Btu, its dissociation in hydrogen and oxygen at the low pressure and temperature used is unlikely. It is expected, therefore, that the insulation will maintain itself as well as in hydrogen, even under short circuits.

VAPORIZATION COOLING AND THE ELECTRIC MACHINES

We now will outline the influence of the vaporization cooling upon the electric machines in themselves, upon rotor and stator, and finally upon machine sets and machine drives.

Coolant Supply and Vapor Flow. Every air gap surface-unit must get exactly the quantity fixed by its needs. For this, the fluid supplied must be subdivided. It can be broken up by rapid motion in the gap, by the fluid streams hitting a hard surface, by atomizing nozzles, or other means. The smaller the fluid-drops the larger their surface, and the easier it is for the vapor to free itself. Clean surfaces and the absence of air make for excellent heat transfer. An oversupply of fluid can be tolerated in a well-guided vapor stream flowing toward the condenser.

A collection of fluid in the rotor is impossible on account of the centrifugal force; in the stator core it is practically impossible. The teeth tips are coolest; the teeth roots hottest. Any fluid getting between teeth and coils is soon stopped by the vapor it creates and is quickly dissolved. The same holds true for the fluid trying to penetrate the insulation. The lowest temperature in the machine, excepting the condenser, is in the air gap. Superheating by the end-windings before condensation makes for an easy control and insures against too much fluid being supplied. The specific heat of steam is about twice that of air. Only about 1/80 of the weight of air is needed at full load.

The cooling fluid can be supplied through small radial channels (from outer circumference to air gap) in the stator core. Due to the absence of air vents, the nearly saturated vapor flows, with smoothly increasing speed, through the air gap toward the end windings. This reversal of the customary direction of flow and the increasing speed are of the utmost importance. The vapor speed midway between the exhaust rings (usually the core sides) will be zero. The flow resistance is therefore one-third of the resistance of a constant flow with exhaust ring velocity. With a rotor surface speed of 300 miles per hour and more, the axial component of the vapor speed, even with a maximum of 60 miles, increases the surface friction only about 3 per cent. From an aerodynamic point of view, vaporization cooling compared with air- or hydrogen-cooling is in a class by itself.

Principles of Coolant Distribution. The cooling of vaporization-cooled machines is independent of the speed and speed

range, outside temperature, and atmospheric pressure. Only those fluid quantities are used which keep critical temperatures constant. Superfluous and undesirable cooling at no-load or small loads is eliminated. The heat movements can be controlled much better and are, therefore, smaller and can be less abrupt. With a 2-dimensional heat field, exact calculations become possible, which are essential for any useful temperature control.

With all losses to be removed by vaporization cooling, a 50,000-kva machine with 2 per cent losses requires at full load 400 gallons of water instead of 40 million cubic feet of air every hour. Using 25 points of supply, water velocities of 6.7 feet per second in the main supply and connecting tubes, and water velocities of 20 feet per second in the hair tubes in the core; the necessary inside diameters for the respective tubes are 5/8 inch, 1/8 inch, and 5/64 inch. The hair tubes distribute the water evenly, independently of the different connecting tube lengths.

Under a constant head, the water flow and the temperature in degrees Fahrenheit are proportional in the hair tubes. The resulting cooling control can serve for many machine applications. With a clogged tube the adjacent hair tubes take over. The hair tubes are so small that they can be led easily through the teeth to the air gap. The spacing of the supply points is arbitrary. The openings at the air gap will be hardly visible.

The number of supply points used at any time can be made dependent upon the fluid quantity needed; the tubes not in use may be connected to vacuum at the supply end and sucked dry. A small regulating valve or pump is sufficient to adjust the supply to the momentary demand. A thermostat in the vapor flow ahead of the condenser can take care of the regulation. Heavy overloads are taken care of by increasing the quantity of vaporization water and can be supported by a better vacuum and an increased condenser water flow. In air-cooled machines, increasing the coolant speed has adverse effects.

Figure 2 shows a basic sketch for a vaporization-cooled machine. The closed housing contains, from right to left, the supply tubes for the fluid, stator and rotor, thermostatic regulator, and condenser cooling coil. The condensed vapor collects in the lower half of the condenser and passes through a cleaning filter in the refillable water container at atmospheric pressure. In service, the vacuum in the machine sucks the water by way of the thermostatic regulator and the supply tubes into the air gap in the quantity needed for the cooling. The regulator is operated by the vapor temperature. The air is removed by the vacuum pump.

The machine is put in service by the hand control, which closes the air inlet valve and the electric circuit. This circuit starts the machine and the pumping set automatically. As the vacuum space is small, the pump will create the necessary vacuum in no time. The machine is taken out of service by the hand control, opening the electric circuits and the associated valve, which lets dry air in the machine. It is all very easy for the attendant.

Machine and Apparatus in One Unit. With the exception of the thermostat between rotor and condenser, all auxiliary apparatus is mounted on the outside of the machine; only small sizes are needed. Since the condenser can be located between the end windings and the outgoing shaft, the machine dimensions need not be increased even for a condenser designed for large overload capacity, shaft sealing, and bearing cooling. Figure 3 shows a sketch of such a machine. It is expected to be smaller than an equivalent air-cooled open-type machine.

The vapor blast sucked in the condenser increases in sealing ability with the load. The condensate passes a filter which removes the dust, oil, and other impurities and then flows through a pump in the supply container. If cast in the bottom of the end shield, the water in the tubing will flow back in the container automatically when the air valve is opened. The auxiliary equipment is the same as for small surface condensers. For machines, say of 400 kva, a combined air pump and condensate pump, and a valve for the cooling water may do. At the place of mounting only the normal electric and the cooling-water connections have to be made.

A small gear pump makes the fluid supply independent of the vacuum. The water velocity and the speed of rotation can be made high. This makes for fine droplets and a large wetted surface. For very large and important machines, where a widely varying load range is expected and needed, the changes in the fluid supply make it desirable to have its distribution over the air gap independent of the quantity of heat that has to be removed.

The fluid speed influences more or less the shape of a fluid spray, the droplet size of the fluid, and the amount of wetted surface. Here a method of supply, such as that used for fuel injection in Diesels is wanted. Carefully metered oil quantities are injected in the cylinders in accordance with the load at accurately predetermined time-intervals and time-durations. Much less exacting specifications will do for the cooling. One is freer in the injection

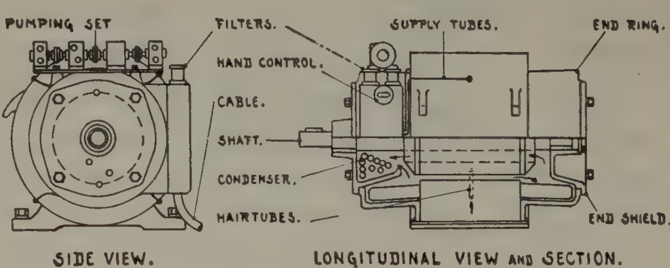


Figure 3. Self-contained water-cooled machine

duration. Instead of one supply point, a whole row of hair tubes can be fed. The timing between the rows is less important. With this type of feed, the number of supply points obviously can be taken at will.

Machine With Air-Cooled Condenser. Where water is objectionable for the condenser cooling or if the quantity of cooling water needed is not available, air cooling can be used. As large vapor velocities are permissible, the vacuum steam pipe, even if of great length, will be of small diameter. With modern welding air-tightness can be guaranteed. Finned tubing and a ventilator in an aerodynamically de-

signed air duct, that turns in wind direction, have advantages (Figure 4). Even for the largest machines, little water is needed for the vaporization cycle. With water cooling, this quantity is maintained or even increased by entrained water when the water temperature is below air temperature. This is not the case with air-cooled machines (vacuum pump). The water level in the container has to be checked every few months.

The thickness of the stator core prevents external sources of heat from appreciably increasing the cooling burden of the machines. This is not so with air-cooled or hydrogen-cooled machines. When using air cooling, the water cooling of the stator core (to be discussed later) is a closed circuit independent of, or interconnected with, the vaporization cooling. An interconnection has the advantage of decreasing the water reserve needed. Furthermore, the condenser and the cooler can be put behind each other in the air-cooling circuit. Only one ventilation fan and air duct are needed in this case, and the total air resistance will increase only a little.

The vacuum seal for the outgoing shaft of air-cooled machines can be similar to the one used with shaft-encircling water-cooled condensers. The vapor intakes are arranged in a circle in front of the bearing. The condensate flowing down can form a spiral ring seal between the atmosphere and the machine vacuum, and exhaust in the water container.

STATOR AND ROTOR

Machines for vaporization cooling are practically one solid block of material, are fully self-contained, do not require openings in the foundation, are compacted by the external pressure, and are (because of the vacuum) as noiseless as hydrogen-cooled machines.

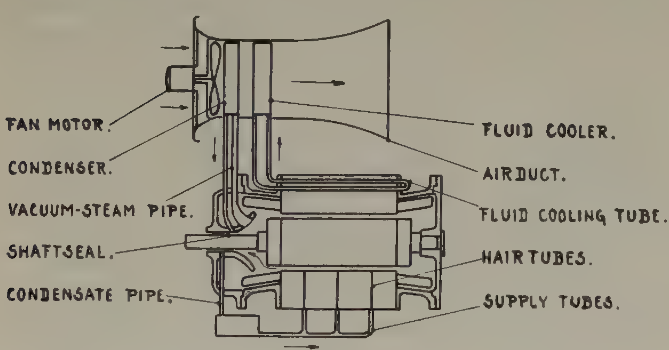


Figure 4. Air-cooled vaporization machine

The Stator Core, and Its Cooling. The stator core can be enclosed airtight in a frame cage, consisting of end rings and longitudinal bars, hollow for strength and for vapor flow (Figure 5). The end rings and end shields can be externally or internally insulated to eliminate condensation, electric flashovers, and so forth. Since the laminated core is somewhat elastic in the axial direction, the balancing of expansion coefficients and temperatures of the conductors and the bars will reduce the relative movements of core and conductor insulation.

Since the windings are well protected on all sides in the cores, the cooling fluid is best applied at the air gap. The hair tubes can be led through and sealed in radial channels in selected groups of laminations. For inspection, a guide tube can be sealed in the core with the hair tube fitting closely in it (Figure 5). With a copper connecting tube of sufficient length, the hair tube can be taken out at any time, inspected, adjusted, and cleaned. Nothing has to be disconnected. The withdrawal of one hair tube from a group of 25, for example, scarcely will influence the cooling. Compare this with air-cooled machines where cleaning, usually made only after considerable overheating has taken place, means a long service interruption.

The sprayed water droplets will be thrown and flattened against the rotor and will move over it, cooling the surface until they have nearly attained the velocity of the rotor. What remains of the droplets is thrown against the stator, cooling the punching-teeth and the wedges.

With great winding height, thick cores, and high-silicon laminations, fluid-cooled holes in the length of the stator are useful (Figure 4). Such holes can control the temperatures at the bottom of the winding slots and at the outer circumference of the core. Insulating the hole walls prevents rusting and leakage. Plastic tubing can form a close fitting lining. The excellent heat absorption and heat transfer of liquids reduces the diameter needed for the holes. High initial fluid temperatures are permissible, the cooling action is still sufficient.

Boiler feedwater, used bearing oil, or used clean cooling water can be taken to cool the stator core. Take note that since about one-third of the losses can be removed this way, the amount of vaporization fluid needed and the size of the condenser can be reduced by one-third. This is obviously impossible with air-cooled or hydrogen-cooled machines. Return bends are useful because they aid in keeping the heat field as two-dimensional as possible and reduce the effects of the slight conductivity of the water.

The Cooling of the Stator and Rotor End Windings. The stator-core end-windings are cooled by the vapor leaving the air gap, passing centrifugally outward through the windings to the condenser. To facilitate this flow and to prevent the short sides of the rectangular end windings from getting more than their share of the moisture, the end windings can be hooded or changed to drop shape.

The rotor coils at each rotor end outside the core can be cooled by the fluid sprays from tubes with their openings between rotor shaft and end windings. The naked innermost turns are cooled at their flat side by the sprays. The cooling effect is maximum here, minimum at the rotor end cap inner-circumference. This temperature progression is opposite to the progression in the embedded length of the coils. The rotor surface cooling never can be truly effective because of the slot insulation and the wedges. The vapor leaving the sides of the air gap will move radially outward as soon as possible, so the rotor end caps will be poorly cooled. All these factors make the mean-temperature gradient in radial direction in the coils small in comparison to the one in air- or hydrogen-cooled machines.

The additional control for the cooling of the end windings helps the choice of the best cooling for the various loads.

Dry steam can leave the air gap. The stator end windings can be cooled by the mixture of both vapor streams.

ELECTRIC MACHINE SETS AND MACHINE DRIVES

The larger sizes of electric machines form a whole with driving or driven machines. With such expensive sets one has to ask oneself if any part such as an end shield, a bearing, a coupling, and so on, is really needed. Vaporization cooling makes possible a natural integration of the machines of sets and drives.

A Vapor Space in Common for Two or More Machines. As vaporization cooling and a satisfactory vapor guidance remove carbon dust fully, all electric machines (including the exciters) can have a vapor space in common. With hydrogen cooling, opening a set for a brush renewal, for example, means a long intermission. With vaporization cooling there is none, an emergency ejector can assist the air pump and the vacuum will be back to normal in no time. The necessary humidity for the brushes is always maintained.

The advantages of a common vapor space are numerous. No shaft seals are needed as one closed housing suffices so that the over-all length of the set decreases (Figure 5). Only one condenser and its set of pumps are needed for the whole machine set. As exciter losses are a few per cent of the main machine losses, larger condensers or pumps are not necessary. Only necessary for each machine is its vaporization water distribution system and its thermostatically controlled regulating valve.

The vacuum pressure of condensing steam turbines is suitable for electric machines. The idea of a vapor space in common is also still good. The two remaining shaft seals will disappear and the ideal condition, imperfectly realized in synchronous condensers, is attained. Neither the condenser nor its auxiliaries will be affected by the one per cent load increase caused by the electric machines. The lost time is not influenced by the vapor space in common.

Contrasted to air-cooled or hydrogen-cooled machines, there is no objection to having the bearings in the common housing. Water in the bearing oil or oil vapor is prevented from reaching the windings by the vapor flow leaving the air gap. The used oil can be withdrawn at a pressure slightly below the machine vacuum by its circulation pump. The oil enters the bearing with about 15 to 30 pounds over pressure. A 30-degree centigrade rise in oil temperature is allowed, the creation of oil vapor is therefore unlikely. The pressure surrounding a bearing does not affect its load capacity.

The Machine Sets. The use of a vapor space in common for the machines of a set not only eliminates all vacuum seals or other main-shaft seals, but also the need for end shields between the machines. If so desired, simple partitions between the machines can be used. For the exciter, which may have to be opened in service for inspection or renewal, an emergency shaft seal and valves in the vapor-exhausts can facilitate maintaining the vacuum during opening.

As the component machines become in a physical sense one unit, instead of remaining just a row of individual machines, the bearings and couplings merit our attention.

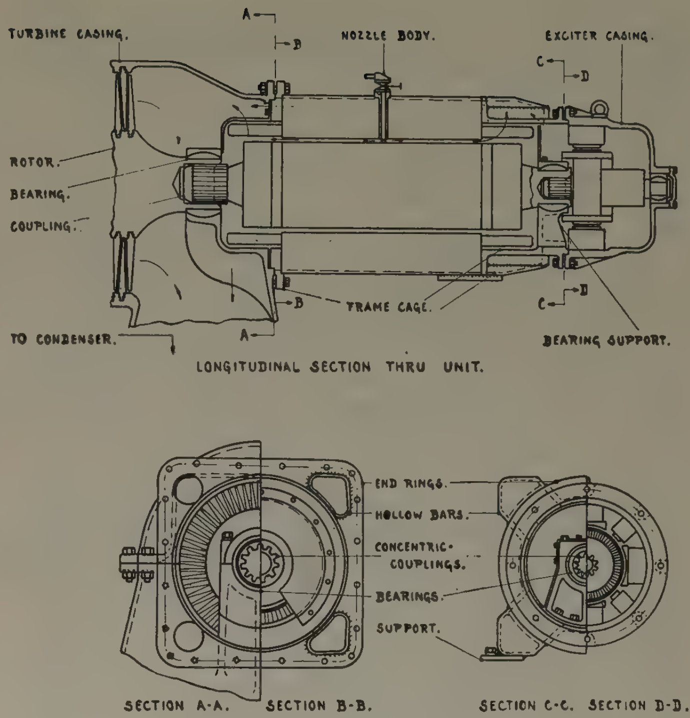


Figure 5. Turbogenerator unit

The question arises as to whether they can be eliminated as were the shaft seals and the end shields.

The rotor shaft of electric machines can be removed axially. This is not the case with normal turbine rotors. The shaft in the bearings is always larger than needed for coupling purposes. Therefore, a splined coupling, with the centers of the bearing surface and the concentric shaft ends coinciding, can be made of the shaft-ends (Figure 5). This coupling acts as a solid one at full speed. Axial movement is needed only for assembly, disassembly, and warming up. All alignment for the inside shaft end is eliminated after the initial assembly. This construction replaces two bearings and one coupling by one time-saving combination between each pair of machines. It is, at present, of primary interest for the exciter.

With a vapor space in common, the exciter can be mounted in place of an end shield on the stator end ring (Figure 5). The flange insures excellent solid centering. With the small coupling-teeth pitch-circle, even a slight angle between the shafts becomes permissible. The commutator is located near its own bearing. One bearing can fix a rotor axially. With plug contacts for the current leads, the exciter can be replaced in only a few minutes. Pilot exciters can use the same construction. The short over-all length of the individual machine shafts and the interchangeable self-contained units (main machine rotors, exciters) are further advantages.

The Drives, Especially Those for Variable Speed. Vaporization cooling can be used in any environment. The size and weight of a machine are a function of its speed. Gear reductions are to be done away with. This draws out attention to synchronous and asynchronous ship and locomotive turbine drives. No separately driven fans are needed as for air cooling. The vacuum pull is fully effective. A 4- or 6-phase system with grounded neutral can be used. This

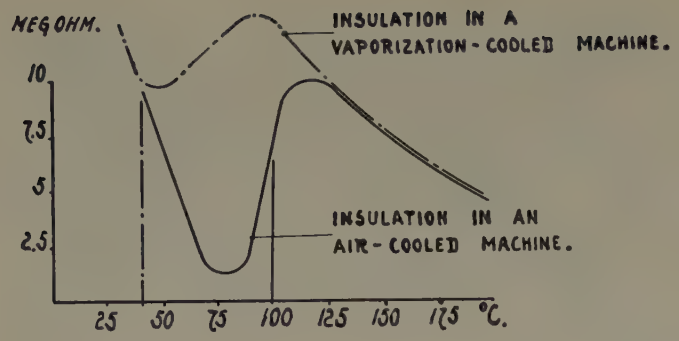


Figure 6. Resistance–temperature curves of hygroscopic insulation

halves the voltages that the insulation is subjected to. Assigning each motor or motor group its own windings in the high-speed generator (for example, 9,000 rpm) presents another means of reducing the voltage. A comparatively low nominal voltage results. The insulation is subjected to the maximum voltage and frequency only at the full-speed, which rarely is used. Moreover, since it takes time to reach full speed; the moisture, should there be any, is removed, before the maximum frequency is reached.

During starting, a short voltage pulse (about two-thirds of maximum voltage) appears across the insulation. After this, the voltage drops to lower values, slowly increasing with the speed. The working conditions for the insulation hardly could be any better. The life of the windings is a major factor in a machine's life. Lack of space prohibits studying the motor drives for which vaporization cooling makes possible simple and effective solutions.

THE VAPORIZATION FLUID AND THE WINDINGS

Introduction. The rules for applying vaporization cooling differ from the rules for air cooling and hydrogen cooling. The cooling medium quantity used depends only upon the heat it must remove.

With constant fluid-regulator setting, the pressure difference between supply and vacuum determines the flow volume. An instantaneous fluid reduction, and a surface temperature rise, are therefore the result of a vacuum breakdown. If the vaporization temperature (vacuum pressure) increases, the temperature difference for the removal of the heat out of the windings decreases. In time, temperature gradients and maximum temperatures increase, with no reduction in load. This makes it more difficult for the fluid to penetrate and damage the insulation.

The exposed end windings are cooled by clean, almost dry vapor; instead of by the wettest and dirtiest gases as is the case with air-cooling. No surface damage therefore can be caused by creepage. The disruptive strength of water is 56.5 kv, of air 25.0 kv for a one-centimeter gap. The resistance of water is about 4×10^{-8} ohms per cubic millimeter, of petroleum 3×10^{-13} ohms per cubic millimeter. In the mist stage and especially in the superheated vapor stage, the resistance will be quite satisfactory.

In air-cooled or hydrogen-cooled machines, water on the windings can cause damage because of through-wetting. A superficial judgment would attribute the same to vaporization-cooled machines. However, what are the facts? Let us look at the insulation resistance. It is used as a criterion for judging if the insulation is in satisfactory condition. A resistance-temperature curve taken of hygroscopic paper fiber is instructive (Figure 6). It shows a dangerous cleft in the curve between 50 and 100 degrees centigrade with a low at about 80 degrees centigrade. The explanation is that only when the vapor tension approaches the atmospheric pressure at 100 degrees centigrade can the moisture be expelled.

In vacuum machines, the vaporization temperature (at one pound per square inch absolute, 100 degrees Fahrenheit) is near the lowest temperature the machine will assume in or out of service. Also water absorption is next to impossible. The insulation remains in top condition over the entire temperature range. Even with water absorption, the cleft has become a hump for the insulation temperatures of the machine in service. All this fully justifies a smaller insulation thickness. The electric insulation value increases rapidly with a decrease in thickness (mica: 1 millimeter, 50 kv per millimeter; 0.1 millimeter, 150 kv per millimeter). The heat resistance and the heat penetration time are proportional to the insulation thickness.

Diffusion of Water and Vapor in the Insulation. The regulation of the vaporization fluid supply according to need keeps the insulation surface temperature practically constant (at least at vaporization temperature). The temperature increases gradually toward the conductor. Diffusion of water in the insulation is impossible. The pores in the insulation can be divided into those connecting with the outside and those that are fully closed. The last need not be considered here, especially since the percentage of the insulation volume taken up by nonsolids is negligible.

All pores have in common the property of being microscopic in size in undamaged insulation. The smaller their size, the less damage can be done by equalizing gas currents or vapor currents. The connecting pores will be filled with air. At the most, this air will be saturated with steam according to the ruling temperature and pressure. Steam is a better insulator than air. When letting dry air in the machine, part of the pores and connecting channels will be closed by the pressure. The remaining pores will fill themselves with dry hot air, this precludes an increase in moisture content of the insulation.

In air-cooled machines (daily temperature cycles, light load, rain, steam) the pores in the insulation gradually can fill themselves with water by condensation, with the resulting vacuum creation. To dry the insulation a volume of vapor thousands of times that of the water is created. The vapor flow or its prevention (clogging) therefore can weaken the insulation seriously and initiate insulation breakdowns. Dirt can do much damage in the insulation. Vaporization cooling eliminates these hazards.

With excessive heating, gases are liberated in the insulation, rapidly increasing with the temperature. In vacuum machines, the surface temperature of the insulation is much lower than in air-cooled machines. Only near the conductors can the temperature be higher. Here the influence of the vacuum pressure is counteracted by the insulation

thickness. Any deterioration through gas formation is obviated.

The Machine Out of Service. The auxiliary machines can be shut down when no heat losses are produced that must be removed or intercepted. To prevent water or moisture laden air from creeping through pumps, seals, and so on, dry air, or inert gas (chemical filter), is admitted through a valve (Figure 2). No water can condense or leak on the windings, the air assumes the mean machine temperature and absorbs all vapor particles and water particles to be found. The possible moisture content of air increases rapidly with the dewpoint. At 60 degrees Fahrenheit there can be 0.011 pound of water in a pound of dry air; at 100 degrees Fahrenheit, 0.043 pound; and at 140 degrees Fahrenheit, 0.153 pound. This is another reason why water in any form is objectionable in the haphazard atmosphere of air-cooled machines. In the ever controlled atmosphere of vaporization-cooled machines, water is not only not objectionable, but invigorating.

After a shutdown of the machine, vaporization fluid is no longer supplied. The condenser remains for some time the coldest part of the machine and will collect the moisture the air absorbs. It is even better to keep the auxiliary machines running for a while. As the winding surfaces assume the mean insulation temperature, they do become hotter than in service. This assures a thorough drying out.

By observing the rate of temperature increase of the vapor flowing in the condenser, an experienced operator can judge closely how dry the machine is. With the machine in service, this observation can be made whenever desired, by cutting off the vaporization water supply for the time needed for the experiment. Out of service, the connection to the atmosphere through a filter keeps a closed-cycle cooled machine dry, independent of time and atmospheric changes. Under exceptional circumstances a trickle of water in the condenser coil can fix a cold spot.

Relative to the exposed winding surfaces, the air volume is only a fraction of the volume in gas-cooled machines. In the latter, for closed circuits, 65 per cent saturation at higher temperatures is figured with. Cooler tube leaks are hard to detect. It is to be noted that the fluid level of the atmospheric water container remains practically constant under normal operating conditions whatever the load. The fluid contents of the closed cooling system will be small. With the slightest leak outward into the atmosphere, or a fluid accumulation in the machine, or leaking condenser tubes; the short-time position of the float in the water container soon will change. This float can actuate an alarm or take any measure desired.

Control by Temperature and Vacuum Pressure. Keeping in mind what already has been discussed, we now will deal with the vaporization fluid control. With superheated vapor flowing in the condenser, one is fairly sure that all the fluid supplied to the air gap is used up. The quantity of heat used is negligible compared with the heat used for vaporization. Also the vapor temperature increases rapidly and makes possible an accurate fluid regulation. The difference between air-gap-surface temperature and vaporization temperature is only of academic interest.

The vacuum pressure determines the temperature of vaporization. During breakdowns so much air can get into the machine that it becomes impossible for the pump to handle it. The vaporization temperature can become higher than the temperature for which the fluid regulator has been set. The conductor temperature and all other temperatures increase, water is prevented from entering the insulation. Vaporization is not resumed before the air-gap-surface temperature permits it. However an instantaneous correction for the new vacuum will be of value.

The regulating valve can be actuated by a combination of a temperature element and a vacuum pressure element (Figure 7). With too large an increase in vacuum pressure, the fluid supply not only is reduced but is cut off. It is not resumed until the vapor flowing in the condenser at the now desired temperature gives assurance of the proper air-gap-surface temperature. This control obviously functions just as well during starting as under load. Co-ordination between turbine starting and generator starting is called for.

With condensing turbogenerators, the maximum power from the same steam volume decreases with an increase in back pressure. This reduces the temperature gradient from conductor copper to insulation outer surface. The maximum temperature hardly will change. The higher vacuum pressure slows down the vapor flow for an instant so that the turbo steam cannot get into the electric machines, even if the turbo goes high-pressure (maximum pressure six pounds, maximum duration one-fifth second).

CORROSION IN VAPORIZATION-COOLED MACHINES

Introduction. The oxygen, dissolved in the water, that comes in contact with metal surfaces can cause corrosion and, under unfavorable circumstances, erosion. The pertaining chemical formulas are metal+HOH=MOH+H and $2H+O=H_2O$. The rate of corrosion is influenced by the number of water molecules coming in contact with a unit of surface. This number is small for a vapor in a vacuum. Take note that corrosion products and atmospheric impurities can absorb moisture at humidities down to 65 per cent and form an invisible water layer. This can be prevented easily with a closed cooling system. Moreover the critical surface temperatures are always above the dewpoint (vaporization temperature).

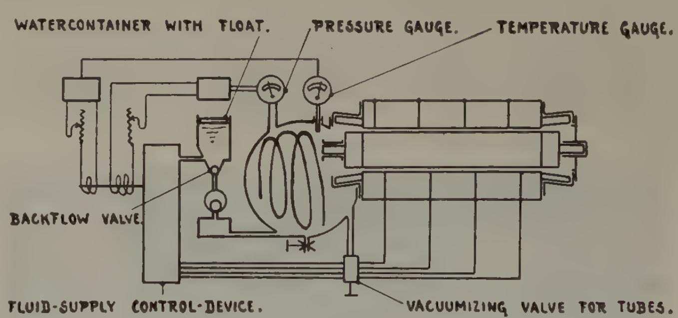


Figure 7. Control equipment of machine

In vaporization-cooled machines, the temperature can

be kept at any level desired, independent of the load. The vaporization temperature is between 20 and 40 degrees centigrade, instead of 100 degrees centigrade. The machine is fully independent of varying and often unfavorable atmospheric conditions. The individual droplets of the water sprays will hit different air-gap-surface spots all the time. The formation of an even thin protective coating on the rotor and stator can be tolerated. The oxides will be dry most of the time.

Furthermore, superheated water released under vacuum pressure explodes and liberates about 95 per cent of the air it contains. Hence the oxygen hardly will come in contact with the rotor surface. It need not come in contact with the stator surface for the vaporizing water will act as a shield. The small quantity of fluid needed to remove the heat losses, the high maximum closed-cycle speed, the continuous removal of air by the air pump, and the removal of impurities by the filter, all assist in keeping the water at high purity and the desired alkalinity to inhibit corrosion. The treated boiler feedwater used for high-pressure steam installations can be used.

Further Data. The total quantity of water needed for a 50,000-kva machine with 2 per cent losses, operating continuously for a year employing vaporization cooling only, gives valuable information. Assume a rotor core surface of 70 square feet. Assume the average heat losses reduced to full-load losses equal to one-third of the hours in a year. Then the core surfaces have to evaporate 20,000 gallons per square foot a year. With one cubic centimeter of air with 35 per cent O_2 per liter, 0.0245 pound of O_2 are liberated each year per square foot. With a full-load cooling-cycle speed of six minutes, only 40 gallons of water are needed. With the water added each year, we can calculate the total solid water contents, which obviously are negligible.

For an evaluation, compare these figures with those pertaining to boilers, where the temperatures are so much higher. All this, coupled with the fact that the vaporization cooling will not have to remove the losses in the bearings and in the stator core, and that the oxygen content of the water usually will be much smaller, show better than words how little corrosion and erosion are to be feared. Machines with a shaft seal are usually smaller in size, while the cooling surface is larger in proportion to the fluid need.

The rapid change from vapor pressure at the pertaining water temperature (vacuum) to a high pressure during the collapse of a vapor space, caused the destructiveness of cavitation. Also there is no such danger in vaporization-cooled machines. The water is supplied in microscopic droplets. The surrounding rotor material therefore will assist in making any blow harmless. This is not possible with solid water jets as in turbines. As to erosion, the rotor surface-speed is about half the turbine blade speed. The water droplet size is controlled (in steam turbines sudden water-cataracts may occur).

The induced rotor currents and stator currents vary continuously in direction and intensity, so this kind of corrosion is unlikely.

CONCLUSIONS

The proposed vaporization cooling system will have for machines the following advantages over the present cooling systems:

1. A saving of 5–15 per cent in copper and punching volume without increasing the current densities or the flux densities. If these are increased the saving is larger.

2. A slightly better efficiency, improved simplicity, a saving of 25 per cent and more in weight, and a saving of 15 per cent in cost of large machines.

3. Just as hydrogen cooling cuts the space needed for air-cooled units in half, so will vaporization cooling cut the space needed for hydrogen-cooled units.

4. Filling or exhausting the machines becomes a matter of minutes instead of hours. Painstaken supervision is not needed, and the yearly outlay for lost hydrogen and scavenger gas can be saved.

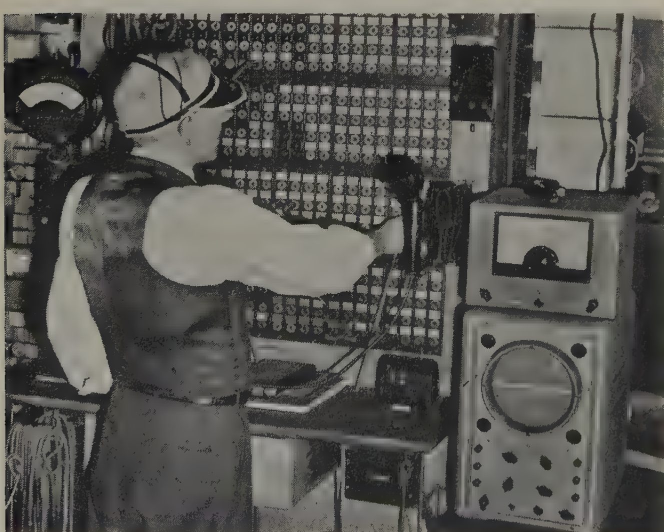
5. The machines are suitable for any size and environment, and for any constant or variable speed. There is a saving in housing, end shields, shaft seals, bearings, couplings, and so on.

6. The auxiliary equipment for the cooling is in wide use, its cost is small and it can be used in part for all the machines of a set.

It must not be concluded that there will be no problems to overcome. A new type of design always requires a lot of work of a most exacting nature. As to structural simplicity, any improvement in some parts is usually partly offset by a complication in other parts. This makes any suggested improvement a matter of evaluation.

In the author's experience in design and development, the problems which caused trouble in practice hardly ever were the ones generally feared, and much overrated. Hydrogen-cooled machines appear to bear me out. Damage to the insulation and explosion danger proved to be little more than scares. Hydrogen leakage and hydrogen contamination, however, made many design improvements desirable.

Radar-Type Fault Finder



Wire chief of Southern Pacific stands at test board of first radar-type fault finder installed on railroad communication lines in this country. Radar unit, atop oscilloscope at right, can spot faults within 100-mile range. Location of fault is shown by wave pattern on screen

Flashover of Suspension Insulators

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FLASHOVER of suspension insulators on steel towers caused by a deposit of moisture on dirty insulators is not unusual on high-voltage transmission lines. These troubles can be prevented by washing the insulators; however, this procedure is expensive so that frequent washing is undesirable. The aim of the investigation described in this article was to determine means of increasing the insulation level of existing lines under fog and dirt conditions so that the insulators could withstand prolonged contamination.

In order to compare the effectiveness of various methods of reinforcing the insulation strength of suspension strings under conditions of contamination, it was necessary to develop a method of artificial contamination and fogging. Studies in the field would have been too time-consuming and complicated by many uncontrollable variables.

A new procedure of artificial contamination was developed which was producible in the laboratory in a short time, gave reproducible results, and which duplicated, to a reasonable extent, service contamination in type, pattern, and electrical effects.

Briefly, the method consists in depositing on each insulator a mixture of 75 per cent, by weight, of fly ash and 25 per cent Portland cement under a carefully controlled procedure of alternate fogging and dusting to produce a pattern of contamination similar to service conditions. Fog conditions were reproduced by directing a stream of wet water vapor, supplied by low-pressure steam, against the insulators. The effect of artificial contamination and artificial fog are shown in Figure 1.

The results obtained from these investigations were

1. Increasing the length of strings of standard suspension insulators increases the flashover voltage under dirt and fog conditions. Increasing the length of the string from 18 units, which is the normal length on the Chicago 220-kv line, to 24 units produced an improvement of about 18 per cent in fog-dirt flashover voltages. This is shown by the lower curve of Figure 2. The study of the effect of lengthening of strings included special investigations of the characteristics of mixed strings of clean and dirty insulators. These special investigations were necessary because of the possibility of flashover of the entire string under fog conditions on account of the voltage concentration across the clean insulators. Measurements showed that actually all the voltage drop was across the clean insulators in a mixed string under fog conditions. It also was observed that the clean insulators were the first to break down in a mixed string. However, this flashover of the clean insulators was not followed by the breakdown of the total string if there was sufficient breakdown strength in the remaining dirty insulators. The breakdown voltage of mixed strings depends upon the ratio of clean to dirty insulators and for the worst combination is about ten per cent lower than the breakdown voltage of an all dirty string. The position of the clean insulators in the string determines the values of the flashover voltage, both of the clean insulators and of the total string. The lower values were observed when the clean insulator was located at the line end.

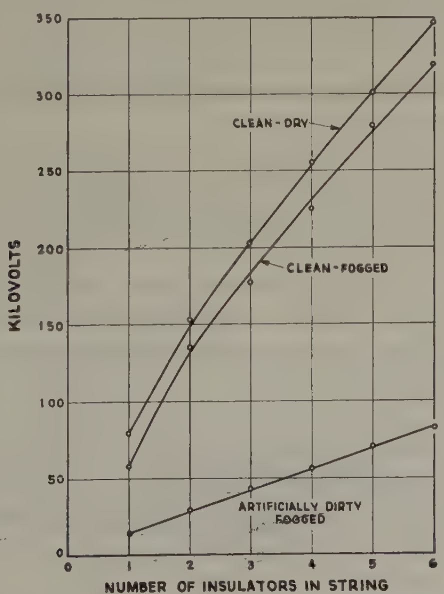

Figure 1. Flashover voltage of suspension insulators

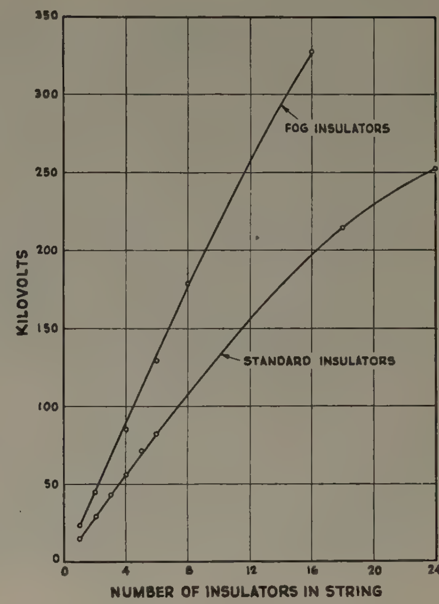

Figure 2. Fog flashover voltages for artificially contaminated standard-type and fog-type insulators

2. Fog-type insulators with nearly 50 per cent more leakage distance than standard insulators showed superior characteristics under fog and dirt conditions. Such insulators are useful where space limitations do not permit lengthening of strings, but they are not applicable to dead-end positions where the large protective under surface of these insulators will be exposed to contamination. Figure 2 shows that 16 fog-type insulators give a much greater factor of safety under fog and dirt conditions than the normal string of 18 standard insulators or even a string of 24 standard insulators.

3. At locations where the lower grooved surfaces of dead-end insulators face a source of contamination, reversal of the insulators results in improved performance according to test results.

Digest of paper 48-307, "Flashovers of Suspension Insulators Due to Contamination," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Carbon Pile Voltage Regulators for Aircraft

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THE CARBON pile voltage regulator used on aircraft is an electromechanical device designed to maintain constant generator voltage under the varying loads and speeds encountered. The speed requirement is especially severe as aircraft generators are driven from the main engines and thus are subjected to a speed range of at least two to one.

The basic components of the carbon pile regulator: an electromagnet, a spring, and a carbon pile; and the electric circuit of which these are a part, are shown in Figure 1.

Briefly, the regulator consists of the electromagnet working in opposition to a spring; the resultant force compresses a carbon pile which serves as the rheostat in the generator field. The force balance relationship existing in the regulator is that the spring force equals the magnet force plus the carbon pile reaction force. These forces and their changes with load and generator voltage were studied. A mathematical analysis was developed and from these equations a graphical method worked out and applied to the design of the regulator. By means of this method, it was found possible to predict that most of the trouble with the normal regulators was caused by using a spring that was too stiff at low forces and not stiff enough at intermediate forces.

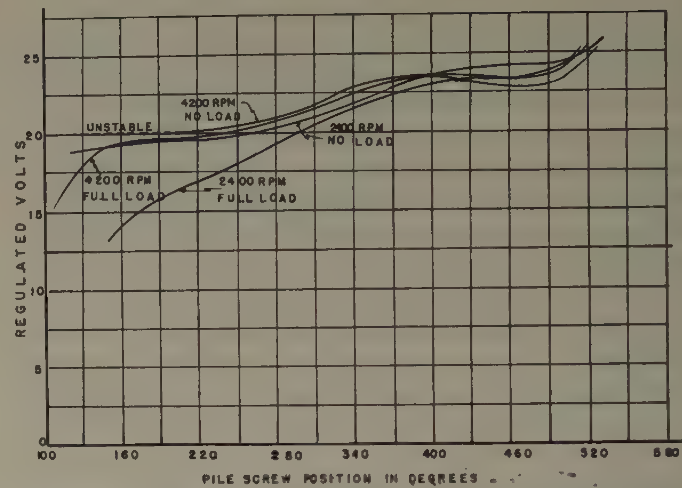

Figure 3. Performance characteristic of regulator with Belleville-type spring

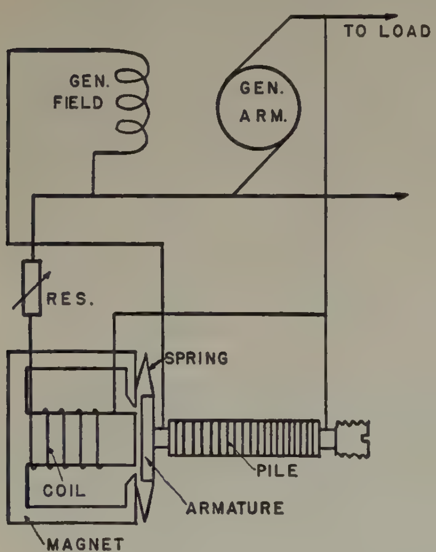

Figure 1. Components and circuit of carbon pile voltage regulator

Using the equations and the graphical method, two types of springs were designed and built. One was a nested cantilever spring and the other a modified Belleville type washer spring. The cantilever was simple to design but comparatively bulky and difficult to assemble and manufacture because of small tolerances. The Belleville spring proves simple to manufacture and is easily assembled. In addition, a new adjustment called the "link spacing adjustment" was added to the regulator assembly. By means of this link spacer, it was possible to move the entire spring assembly with respect to the face of the magnet to obtain an optimum operating position. Several regulators were built using the new spring and the "link spacing adjustment." These showed an increased adjustment range and improved stability.

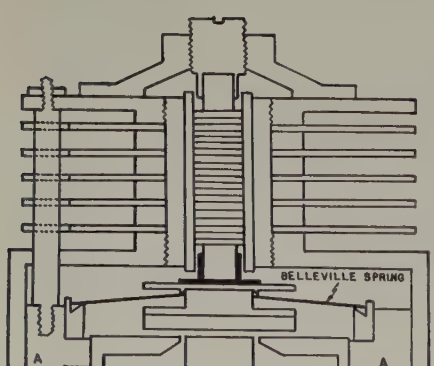

Figure 2. Sectional view of regulator with Belleville-type spring, illustrating the "link spacing adjustment"

Figure 2 shows a sectional view of a regulator with Belleville-type spring, in which the parts providing the adjustment have been marked *A*, *B*, and *C*. Figure 3 shows the regulator characteristics obtained with the Belleville springs. These compare well with the characteristics obtained with the nested cantilever spring, and although not quite as flat, it is thought that the decrease in size and number of parts, as well as the simplicity of assembly and less critical tolerances, make it a more practical unit.

Digest of paper 48-213, "Analysis and Redesign of a Carbon Pile Voltage Regulator for Aircraft Generators," recommended by the AIEE transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, Washington, D. C., October 5–7, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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A System for 8,000-Cycle Program Transmission

With the rapid expansion of broad-band carrier telephone systems throughout the United States, the use of these facilities for program transmission has become desirable. This article describes a carrier program system capable of transmitting a band about 8,000 cycles wide.

FROM the beginning of radio, the Bell System has supplied the broadcasting industry the needed interconnecting links between broadcasting stations, studios, and other program originating points. For many years these facilities have been provided at audio frequency over loaded cable pairs,[1] or over open-wire lines.[2] Because present growth of message facilities over main traffic routes is predominantly in broad-band carrier telephone circuits, it has become desirable to adapt these new carrier facilities for the transmission of high-quality program material.

The carrier program system to be described operates in conjunction with message circuits and provides a band width of about 8,000 cycles, employing the line frequency space normally occupied by three message channels. It can be applied to the type *J*, type *K*, and type *L* carrier systems[5, 3, 7] which operate on open wire, multipair cable, and coaxial cable facilities, respectively. With a slight modification, which soon will be made available, a circuit having a 5,000-cycle band can be accommodated by displacing only two message channels. Program signals having a band width of only 5,000 cycles can be transmitted over the full band system also, and require less complete equalization and maintenance than full-band transmission.

The carrier program system was developed by 1942 but, delayed by the war, its first commercial application was not until early in 1946 on the transcontinental type *K* carrier route west of Omaha, Nebr. It is now in use in all sections of the United States, particularly the West and South, on type *L* as well as type *K* systems and has been tested successfully on type *J* systems.

In general, a band width of 5,000 cycles is transmitted in these applications.

OBJECTIVES

Existing audio-frequency program circuits may be as long as 7,000 miles, may have 100 or more dropping or bridging points, any one of which occasionally may transmit to all of the others, and may be arranged for automatic reversal of the direction of transmission by means of a control signal. In order to co-ordinate with these existing circuits and studio loops, a carrier program system must be capable of duplicating this flexibility while maintaining the desired standards of quality of transmission.

In setting an objective for the standards of transmission quality of this new system, the trend towards wider band widths has been recognized. Most of the major networks now use a 100- to 5,000-cycle band width. A large part of the present audio-frequency cable facilities, however, can be arranged to transmit a band from 50 to 8,000 cycles. It was decided to match this grade of transmission in the design of the new carrier system.

For the cases where still higher quality is desired, a 15-kc carrier program system has been developed and is available now.

DESIGN FEATURES

The 12-channel bank of message circuits forms the basic building block of the broad-band carrier telephone systems.[4] In the channel bank, each of the 12 voice-frequency channels modulates one of 12 carriers spaced 4 kc apart from 64 to 108 kc. The lower sideband resulting from each modulation is selected by a band filter and combined with the other 11 lower sidebands to give a channel group occupying the frequency space from 60 to 108 kc. The channel group then is modulated further as a unit to its

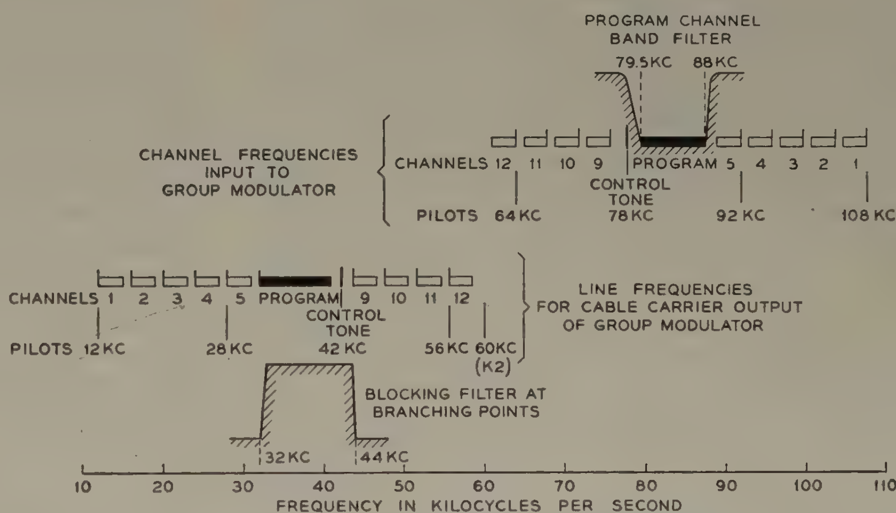

Figure 1. Frequency allocation for one 8,000-cycle program channel and nine message channels in cable carrier systems

A condensation of three conference papers: "A Carrier System for 8,000-Cycle Program Transmission," by **R. A. Leconte, D. B. Penick, C. W. Schramm,** and **A. J. Wier,** all of the Bell Telephone Laboratories, New York, N. Y.; "Band Pass Filter, Band Elimination Filter, and Phase Simulator Network for Carrier Program Systems," by **F. S. Farkas, F. J. Hallenbeck,** and **F. E. Stehlik,** all of the Bell Telephone Laboratories, New York, N. Y.; "Delay Equalization of 8-Kc Carrier Program Circuits," by **C. H. Dagnall** and **P. W. Rounds,** both of the Bell Telephone Laboratories, New York, N. Y.; presented at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949.

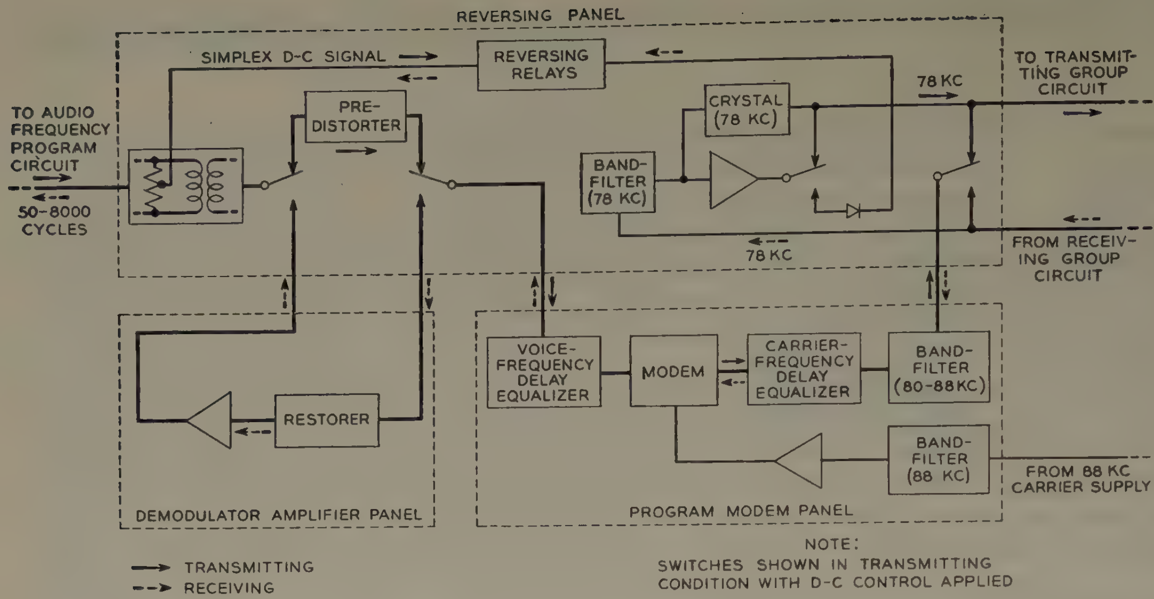

Figure 2. Block schematic of carrier program terminal

appropriate place in a broadband spectrum for transmission over the line.

In order to arrange a channel bank for program transmission, message channels 6, 7, and 8 are disabled, clearing a space from 76 to 88 kc in the group-frequency spectrum. In a program terminal separate from the channel bank, an audio-frequency program modulates an 88-kc carrier derived from the message channel carrier supply. Its lower sideband is selected by a band-pass filter and combined with the lower sidebands of message channels 1 to 5 and 9 to 12 to give a group-frequency spectrum shown diagrammatically in Figure 1. This figure also shows the same spectrum after it has been modulated with a 120-kc group carrier for transmission over a type *K* line. Other line-frequency spectra are produced similarly in type *J* and type *L* group modulators.

The control signal in an audio-frequency program circuit is a d-c signal superimposed on the program pair. It is used to supervise the direction of transmission and effects rapid reversals as needed, when networks are rearranged during program breaks. In a carrier program circuit a carrier-frequency signal, 78 kc at the terminal, is transmitted along with the program channel, outside of its frequency band, to perform this reversing and control function. The carrier system, over which the program channel is transmitted, is constantly in operation in both directions simultaneously. A reversal of the direction of transmission, therefore, is accomplished by switching the

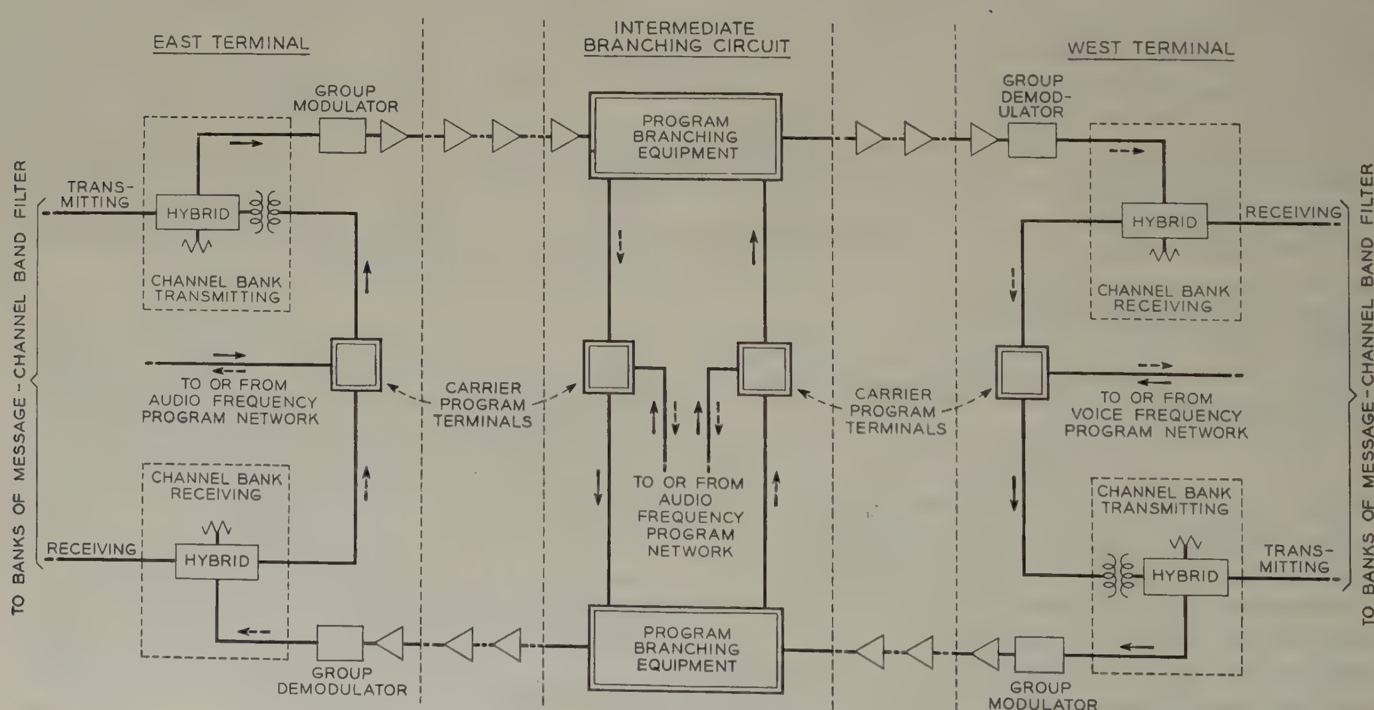

Figure 3. Program link on cable carrier system with one intermediate branch point

carrier program terminals between the incoming and outgoing carrier group circuits as required. A reversing and control circuit in the carrier program terminal converts an incoming d-c control signal to 78 kc for transmission over the carrier system, reconverts it to direct current at the receiving end, and performs the appropriate switching operations.

The arrangement of the circuit elements in a carrier program terminal is shown in the block schematic of Figure 2. The transmission circuit wiring is shown in heavy lines.

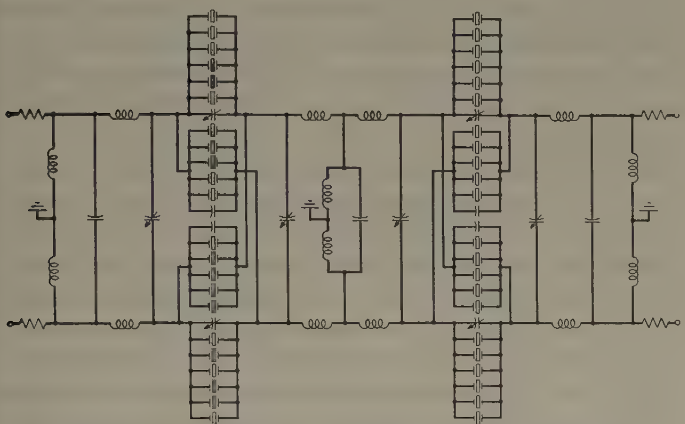

Figure 4. Schematic of the program channel band filter

The reversing and control circuits are indicated in lighter lines.

Figure 3 shows a carrier program system including two terminals and a branching point as it is connected to a type *K* system. The program equipment is identified by double-line blocks.

The carrier program terminals are connected into the program networks in the same way as the audio-frequency facilities, through equalizers, amplifiers, bridges, and reversing circuits. Connected as one leg of a reversible bridge, a carrier program circuit may feed or be fed by any of the other legs, which may include cable, open-wire, or studio loop circuits, or other carrier circuits.

TERMINAL CIRCUIT

As Figure 2 indicates, a carrier program terminal consists of three elements: a modulator-demodulator or modem, a demodulator amplifier, and a reversing and control circuit. The heart of the terminal is the modem, which translates the program material from its original audio band to its desired position in the carrier-frequency spectrum or vice versa. It consists essentially of the nonlinear varistor to which the carrier and program material are applied, and the band filter which selects the desired sideband from the modulation products. The varistor is connected in the double-balanced bridge arrangement in which the signal, carrier, and sideband circuits are each balanced against the other two. It is composed of copper-oxide elements and in order to meet the conflicting requirements for high carrier-to-signal ratio and low transmitted carrier, a high degree of balance between the varistor bridge arms must be maintained. This is accomplished by building up each bridge arm of 16 copper-oxide elements connected in series-parallel. An amplifier provides the required carrier power and a narrow-band filter gives additional suppression to carrier frequencies of other channels which are fed from the same carrier supply.

The band filter represents a major development in itself and incorporates a number of advances in the art of filter design. One of its features is an exceptionally sharp rise in attenuation in the neighborhood of the carrier frequency. The unwanted (upper) sideband is attenuated by at least 20 decibels for signal frequencies of 40 cycles or higher, while the wanted (lower) sideband, less than 0.1 per cent different in frequency, is passed with substantially no distortion. Since there are two filters in tandem in a carrier link, there is always a minimum suppression of 40 decibels to the unwanted sideband of all signal frequencies above 40 cycles. The realization of this performance characteristic requires filter elements having dissipation factors of 80,000 or higher, practically obtainable only by using quartz crystals. If the filter were constructed of complex lattice sections only, the physical limitations of the quartz elements would limit the obtainable band width to about 7,300 cycles at the 88-kc carrier frequency. By combining the complex lattice sections with electrical ladder sections, however, it has been possible to extend the band width to about 8,500 cycles and still remain within the range of commercially obtainable crystal elements. Another feature of this filter is its high discrimination to frequencies outside of its pass band, which is needed to suppress crosstalk from the adjacent message channels. Considerations of frequency stability result in the use of +5-degree X-cut crystals vibrating in their fundamental longitudinal mode rather than the −18-degree X-cut crystals used in many other

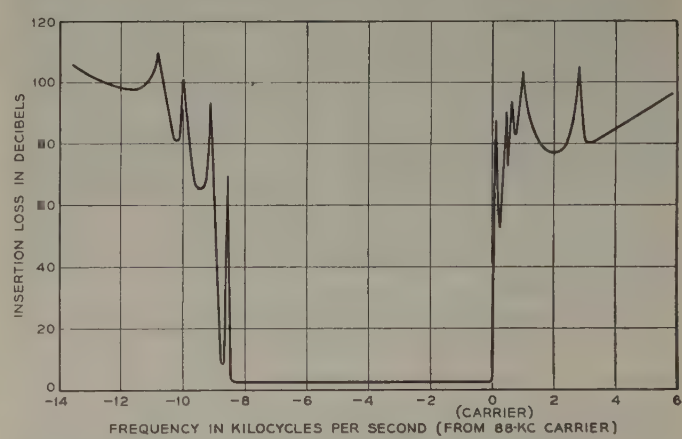

Figure 5. Band filter insertion loss characteristic

filters. The schematic of the filter as constructed is given in Figure 4. The filter is split into two sections to ease the attentuation burdens on each and allow wider manufacturing tolerances to be placed on the filter elements. A total of 44 components are required, 22 of which are balanced quartz crystal plates arranged in groups of five or six in four hermetically sealed containers, of which two are

evacuated, and two are filled with dry air at atmospheric pressure. The filter weighs about 30 pounds and occupies seven inches of vertical space on a standard 19-inch mounting frame. Its attenuation characteristic is shown in Figure 5.

The delay characteristic of the filter is given by curve *A* of Figure 6. For more than three carrier links in tandem, the total delay distortion introduced by the two filters per link is large enough to be disturbing. Delay correction, therefore, is provided by two equalizers in each terminal to reduce terminal distortion to an amount represented by curve *B* of Figure 6. The design of the equalizers was simplified by an electrostatic analog[8] in which the array of zeros and poles of the insertion loss factor, plotted on the complex frequency plane, Figure 7, are replaced by infinitely long charged filaments perpendicular to the plane, the zeros with positive charges, the poles with negative charges. It may be shown that the delay at any frequency ω is proportional to the field intensity perpendicular to the ω axis.

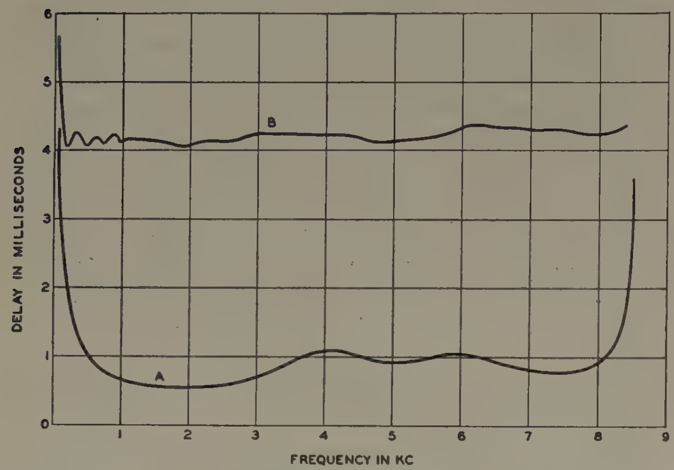

Figure 6. Delay characteristic of carrier program terminal before and after equalization

The shape of the delay curve, ignoring ripples, may be obtained by assuming that the filament charges are spread over capacitor plates passing through the filaments as shown in Figure 7.

Application of the analog shows that 29 basic delay sections are needed, provided that the first three sections operate at the carrier frequencies. Each basic section consists of a lattice with antiresonant series arms and resonant cross arms. The audio-frequency sections are of conventional coil and capacitor types. The carrier-frequency sections employ quartz crystals because the rate of change of delay requires stiff reactances, high Q's, and high-temperature stability. A configuration adaptable to crystal elements is obtained by combining the three basic sections into a single lattice. Attenuation distortion resulting from dissipation in the elements of the equalizers is corrected by adding a few minimum-phase attenuation equalizing sections to the 26 delay sections of the audio-frequency equalizer and by combining compensating dissipative elements with the lattice arms of the carrier-frequency equalizer.

The demodulator amplifier is a conventional 2-stage resistance-coupled amplifier. It is stabilized by 25 decibels of feedback to a nominal gain of 38 decibels, variable over a 12-decibel range by a potentiometer in the feedback circuit. The transmission characteristic is flat within 0.3 decibel over a 35- to 15,000-cycle frequency range. The output impedance is stabilized by the use of an output bridge for obtaining the feedback voltage. This amplifier feeds a −10-volume unit point in the circuit and can deliver up to 18 decibels above one milliwatt of output. Noise is kept to a minimum by operating the input stage vacuum tube at reduced voltages, mounting it and the magnetically shielded input transformer on a vibration-reducing suspension, and providing heavy filtering for the *A* and *B* battery circuits.

The limiting source of noise in any communication system is usually the transmission medium. In the carrier program system, the transmission medium is a carrier system which introduces noise energy equally distributed over the program band. The program energy being transmitted, however, is concentrated heavily at the lower frequencies. In order to increase the signal-to-noise ratio without an increase in total transmitted power, a predistorting network is introduced ahead of the modem, which attenuates the lower frequencies relative to the higher. The total discrimination is about 18 decibels, distributed symmetrically on a logarithmic frequency scale above and below 1,500 cycles. A restoring network having an inverse characteristic is inserted in the receiving program path to return the program energy distribution to normal.

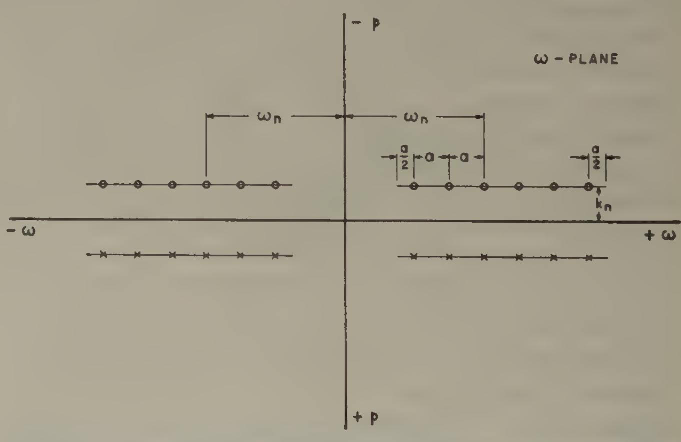

Figure 7. Zeros and poles of a complex delay network based on the capacitor-plate design

The noise improvement thus obtained is about seven decibels.

The reversing circuit consists of a set of relays and a 78-kc amplifier-oscillator. The 2-stage feedback-stabilized tuned amplifier raises the level of the 78-kc receiving control signal selected from the incoming carrier group by a narrow-band crystal filter. A copper-oxide rectifier converts the amplified signal to direct current to operate the receiving

relays, which connect the transmission circuits to the incoming carrier group and send on a d-c control signal over the audio-frequency pair leaving the program terminal. In the transmitting condition, under the control of an incoming d-c signal, the same amplifier, modified by the connection of a 78-kc crystal from output to input, generates the 78-kc control signal transmitted over the outgoing carrier group.

BRANCHING CIRCUIT

Because of the operating requirements of a radiobroadcasting network there is need for complete switching flexibility. For the greater part of their operating time, scores of broadcasting stations in a national network need only a receiving connection from the network. Any one of them, however, sometime may originate a program to feed to the network, and there is an occasional need for blocking a program received from one part of the network in order to transmit a different program to another part. These requirements impose special problems in a carrier program circuit at intermediate points where it is desired to connect to a program channel without terminating the associated message channels and without introducing into the through circuit the transmission distortion of a pair of tandem program terminals. These requirements are met by the branching circuit. It provides hybrid networks for bridging carrier program terminals onto the incoming and outgoing carrier transmission paths, modulators, and demodulators for converting the transmission frequency range to that of the program terminals, and alternate paths for the through transmission, one for passing all frequencies and one for blocking the program and control signal frequencies. Selection of the alternate transmission paths is controlled by relays in such a way that the transfer between the program transmitting and program blocking conditions can be made at any time with a minimum of disturbance to the associated message channels.

These branching arrangements, developed for type *K* systems, have been adapted also for use with type *L* groups. Blocking and bridging functions are provided as they are for type *K* and, in addition to the complete branching circuits, include simplified arrangements which make use of otherwise idle groups for carrier program circuits without message channels. A simplified arrangement for type *K* use is provided also for merely removing the reversible program channel from the carrier circuit without terminating the message channels.

EQUIPMENT

Two carrier program terminals together with fuse panels for 24- and 130-volt battery supply for several bays are mounted in one standard cable-duct-type bay, 19 inches wide and $11^1/_2$ feet high, as shown in Figure 8. On the wiring side of the equipment, each of the three units of each terminal is provided with its own metal cover to furnish the necessary electrical shielding as well as physical protection. Connections to carrier systems are made through carrier program high-frequency patching jacks on a 4-wire basis and to the program circuits through audio-frequency testing jacks on a 2-wire basis.

A complete type *K* branching circuit consists of two sets of line bridging equipment and two carrier program terminals. The line bridging equipment is mounted in a standard cable-duct-type bay, one of which is shown beside each terminal bay in Figure 8.

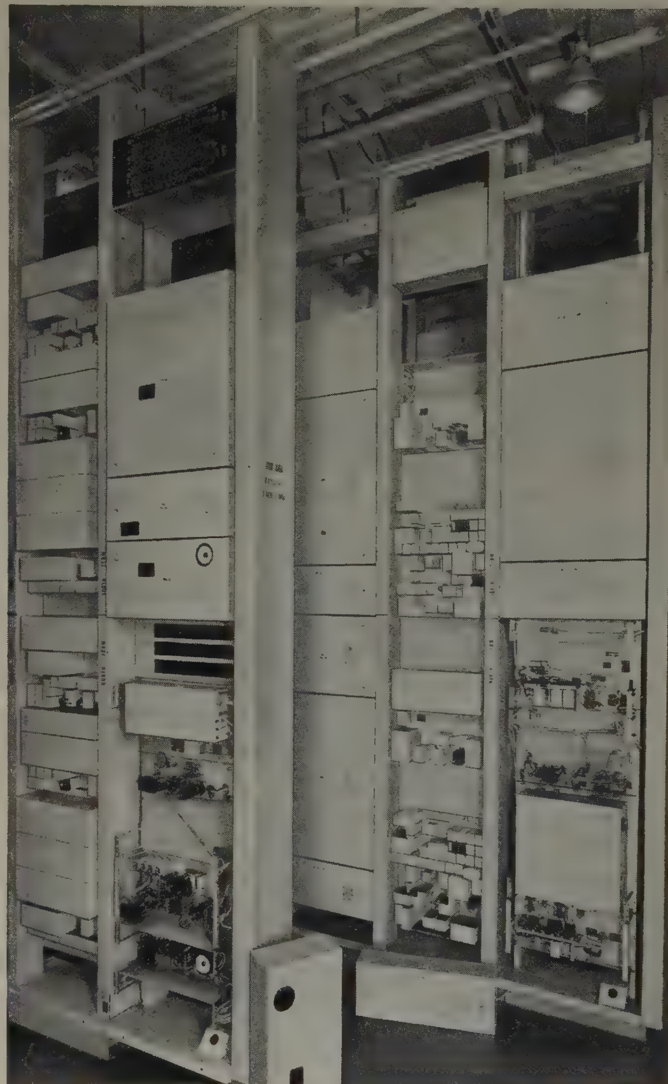

Figure 8. An early installation of carrier program terminals and associated type K branching circuits, showing (left) the front of line branch bay and of terminal bay and (right) the rear of terminal bay and of line branch bay

This equipment, normally associated with type *K*2 repeater equipment,[6] is arranged similarly with wiring and panel covers on the rear.

SYSTEM PERFORMANCE

The longest commercial network circuits now in operation are in the order of 7,000 miles long, including the transcontinental backbone route and feeder circuits along the Atlantic and Pacific coasts. On the assumption that these routes some day may be largely in carrier, exhaustive tests were made in 1947 of carrier program transmission applied to type *K* systems between Omaha and Los Angeles, Calif.,

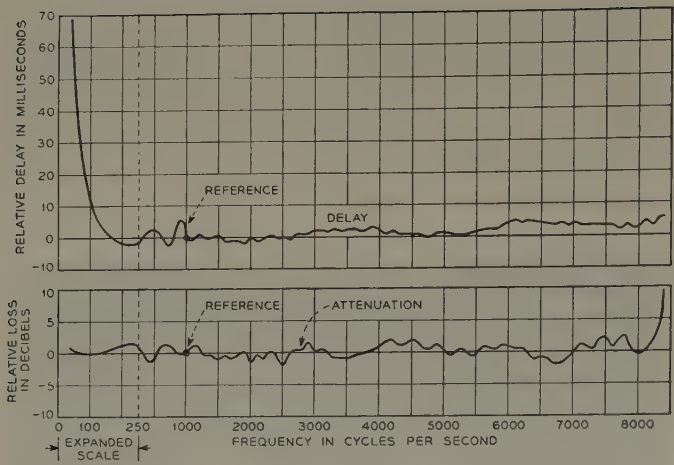

Figure 9. Measured attenuation and delay distortion characteristics of a typical 10-link circuit; this circuit was 7,300 miles long

looping back and forth as required to build up long circuits. Live program material transmitted around a 7,300-mile loop consisting of ten carrier links in tandem was judged by experienced and critical observers to be of excellent quality. Attenuation and delay characteristics of this circuit relative to the 1,000-cycle point are shown in Figure 9 and indicate that design objectives are met with enough margin to justify practical operation over about 13 links in tandem. Background noise was about 53 decibels below the peak signal. Frequency shift caused by the differences in carrier frequency at the 20 terminals was less than two cycles. The time required for a complete reversal counting from the initial control signal release was three seconds. Shorter lengths, of course, will have even better performance. These characteristics, while they do not represent perfection in transmission quality, strike a balance between the various engineering limitations, which makes this system compare favorably with the best facilities previously available.

CONCLUSION

At the end of 1948, three years after the first installation, there were approximately 75,000 miles of carrier program circuits in service, about 70 per cent of them established full time. This is a substantial proportion of the total mileage of all grades of program service, which is in the order of 175,000 miles. The portions of the main transcontinental routes formerly carried by open-wire lines are now in carrier cables.

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Measuring Copper-Nickel Coatings Magnetically

A convenient, nondestructive magnetic method for determining the thickness of composite copper-nickel coatings electrodeposited on steel has been developed by Abner Brenner and Eugenia Kellogg of the National Bureau of Standards. The method involves the measurement of the attractive force between the plated specimen and two permanent magnets of different strengths. The values thus obtained are used, in conjunction with a set of previously determined calibration curves for each magnet, to obtain the total thickness of the coating and the relative thicknesses of the copper and nickel layers.

Composite coatings, in which nickel is deposited over a layer of copper, are used extensively in the automotive and other industries for the economical protection of steel against corrosion. While the effectiveness of these coatings is usually somewhat inferior to that of pure nickel plate, the copper required is less expensive than the extra layer of nickel that would be necessary otherwise. As the protective value of the composite coatings depends largely on their thickness, it is important to have a convenient means for measuring this property. Microscopic examination of the plating necessitates destroying the sample.

The magnetic method, which eliminates the necessity of cutting the specimen and is easily and rapidly applied, utilizes the principle of the magne-gage, an instrument originally designed at the Bureau to measure the thickness of single electrodeposited coatings on the basis of the attraction between a small permanent magnet and the plated sample. The magne-gage is essentially a spring balance, on the arm of which a magnet is suspended in contact with the coated surface. A helical spring is so attached that, when wound by means of a knob, it exerts a force tending to detach the magnet from the surface. If, as is ordinarily the case, the coating is less magnetic than the object plated, the required force, as indicated on a dial adjacent to the knob, will be greater for thinner coatings. Total thicknesses of composite coatings ranging from 0.0005 to 0.003 inch can be determined within about ten per cent. The thickness of each component layer of similar coatings can be measured to an accuracy of about 15 per cent.

New Carrier-Current Equipment for Telemetering

R. W. BECKWITH
MEMBER AIEE

THE RAPIDLY EXPANDING USE of telemetering by power companies is made possible largely by carrier-current channels. Anticipating the requirements of present-day telemetering needs, a narrow-band frequency-shift type of equipment was developed; this equipment has received wide acceptance.

A review of the forms of telemetering now in use with carrier-current channels shows in some cases that the carrier transmitter must be controlled by a single opening and closing contact and must duplicate this contact performance at the receiving end. In one frequency type of telemetering, the carrier transmitter must accept a variable low-frequency alternating voltage and must reproduce this voltage at the receiver output terminals. In order to make possible the use of the maximum number of carrier-current channels on a given power system, it becomes very important to conserve the carrier-frequency spectrum and utilize the minimum possible power. Since many telemeter channels are required to operate over long distances, the equipment must be capable of operation through high attenuation with good independence from noise, interfering signals, and wide changes in attenuation. A new type of carrier-current equipment fulfills these requirements.

The substantiated theories of frequency modulation have been applied to the signals from 0 to 30 cycles per second as required for telemetering. This shows that the use of a very narrow-band frequency-shift system will provide the greatest useful range per unit of transmitted power. Of equal importance to range, these principles indicate a more economical use of the carrier frequency spectrum and excellent independence of received telemeter signal from variation in received carrier voltage.

Quartz-crystal circuits are used to generate the frequency-shift signal and to detect the small (0.06 per cent) shift in transmitted frequency. The receiver uses a crystal filter and crystal discriminator. One type of transmitter uses two crystals and a means for switching output; one uses a crystal and reactance-tube circuit for shifting frequency.

An important feature of the equipment is the independent operation of each channel, while at the same time many channels can operate through common coupling and tuning equipment. (As many as 25 channels can be accommodated in a 12 per cent wide frequency band.) A valuable flexibility results from the fact that it is not necessary for all transmitters of a group to be located at one point, making it possible to transmit a number of telemeter readings from several outlying stations to a central control point, all in the same band of frequencies. It is possible to transmit two groups of telemeter frequencies in opposite directions with five per cent separation between groups; unidirectional channels in a group are 0.5 per cent apart.

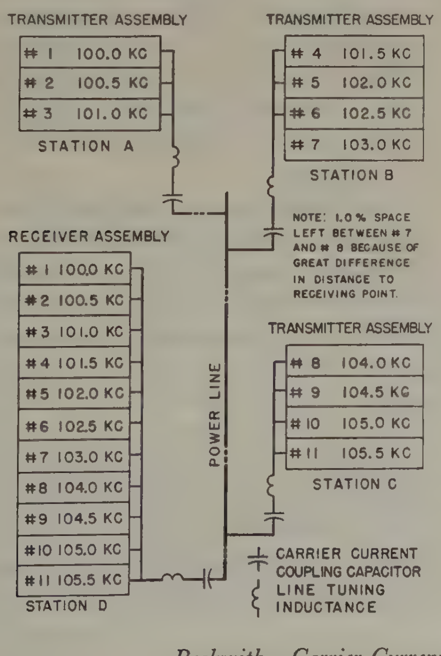

Figure 1. Block diagram of radial type of application

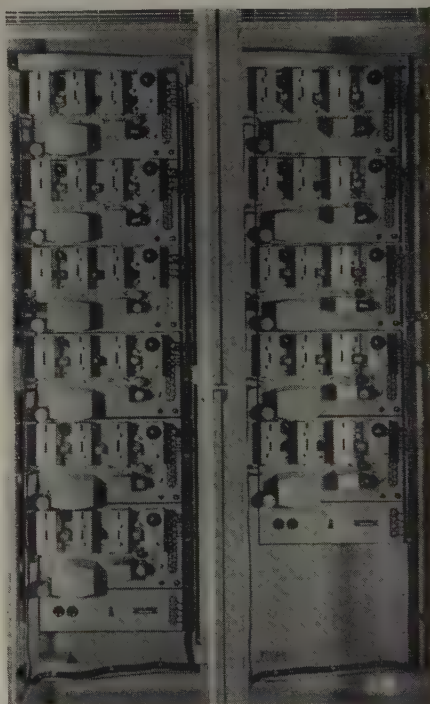

Figure 2. Assembly of 11 parallel-connected carrier-telemeter receivers

This equipment is extremely versatile in its application. Figure 1 is a block diagram of one type of application in which telemeter readings are transmitted from a number of generating points to a central dispatching station. Figure 2 shows such an assembly of 11 receivers now in operation.

Digest of paper **48-297**, "Characteristics of New Carrier-Current Equipment for Telemetering and Load Control," recommended by the AIEE carrier current committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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"Hy-Therm" Copper—An Improved Conductor

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THE SIZE of conductors for overhead lines generally has been selected on the basis of obtaining the required voltage regulation and most economical power loss. Usually, these criteria result in a larger size than would be necessary from a thermal limitation. However, there have been many instances, such as in short tie lines, where it has been necessary or desirable to load the conductors to their thermal limit. For this reason there has been a continuing interest in the determination of both the maximum continuous and short-time emergency overload capabilities of the conductors. Insufficient data on the annealing characteristic of copper prevented the establishment of uniformly acceptable limits.

In conjunction with the development of a new brand of copper, trade-named "Hy-Therm," having improved annealing characteristics permitting higher current loading, the authors have made an extensive investigation of the annealing characteristics of hard-drawn copper wire as affected by: chemical composition; heat and time—with and without tension; intermittent heating; and manufacturing technique. The results indicate that:

(*a*). The effect on annealing of noncuprous elements is the resultant of a complex interrelationship of many variables, and the net result appears to depend primarily on the ore and refining processes.

(*b*). The effect of continuous heating is to start annealing immediately at a rate depending on the temperature and type of copper.

(*c*). The effect of intermittent heating is directly cumulative.

(*d*). The effect of externally applied tension is to increase the rate of annealing.

These data enable continuous and short-time current-carrying capacities of overhead lines to be calculated more accurately.

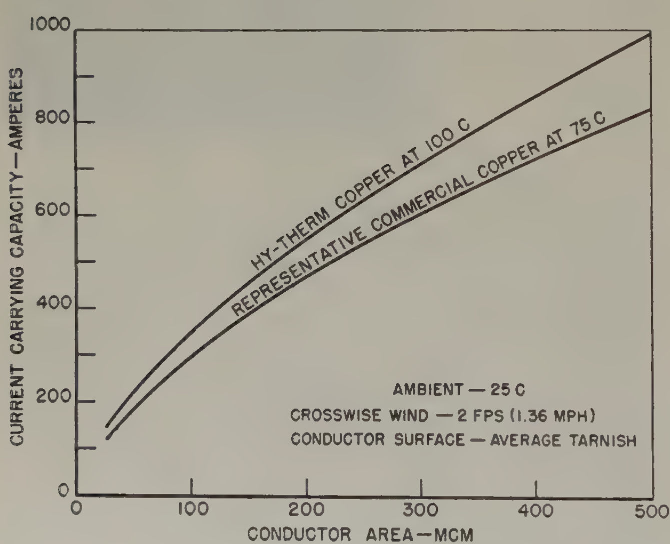

Figure 1

The new brand of copper, by virtue of increased resistance to annealing, permits higher current-carrying capacity and longer useful life under load, with no significant loss in conductivity. This new brand of copper is produced by adding minute amounts of hardening agents to very pure electrolytic copper. Because of its controlled composition, it has consistently uniform properties. The types and amounts of added material are so chosen that their effect on purity and conductivity is negligible. The purity and conductivity of Hy-Therm copper are well in excess of the minimums specified in American Society for Testing Materials Bulletin *B5-43*.

On an equivalent annealing basis, tests show that Hy-Therm copper can withstand a continuous operating

Table I. Temperature-Time Relation for Five Per Cent Loss in Initial Strength (Hard-Drawn Wire)

Annealing Temperature, Degrees Centigrade	Annealing Time, Hours: "Hy-Therm" Copper	Annealing Time, Hours: Representative Commercial Copper
65	(a)*	24,000
85	(a)*	1,950
100	24,000	200
125	1,100	15
150	63	2.3

* Indeterminate to date; 1.4 per cent loss in strength occurs in 40,000 hours at 65 degrees centigrade and in 21,000 hours at 85 degrees centigrade.

temperature 35 degrees centigrade higher than that for representative commercial copper. Accepting that maximum operating temperatures of 75–80 degrees centigrade have been satisfactory in the past, Hy-Therm copper could be rated at 110–115 degrees centigrade. However, since it is probable that future lines will be designed to closer operating limits than formerly, a more conservative value of 100 degrees centigrade has been selected for current-carrying-capacity calculation. On this basis, Hy-Therm copper will carry approximately 20 per cent greater current, as shown in Figure 1.

Considering five per cent loss in initial strength to be a conservative basis for comparing anticipated useful life as affected by annealing, Hy-Therm copper will retain its strength approximately 100 times longer at the same temperature or approximately $3^1/_2$ times longer at rated operating temperature when compared to representative commercial copper. This is shown in Table I.

Digest of paper **49-3**, "Hy-Therm Copper—An Improved Overhead-Line Conductor," recommended by the AIEE transmission and distribution committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

L. F. Hickernell is chief engineer, **A. A. Jones** is manager of the engineering department, and **C. J. Snyder** is supervisor of the metallurgical laboratory, all with the Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.

German Electronics in World War II

A. H. SULLIVAN, JR.
MEMBER AIEE

The above-pictured metal lens antenna simulates an optical system by utilizing a group of wave guides as the elements of the high-frequency lens. This piece of equipment, as well as many others, was examined during an investigation of German technical developments of World War II and is described in this article.

DURING the past three years, the scientists and engineers of the United States Army, Navy, and Air Force, in co-operation with American industry, have been conducting an intensive investigation of the German technical developments of World War II. Tons of equipment and documents have been examined, but much of the material proved to be of little use and had to be discarded.

However, quite a large amount of it had worth-while features of value to American industry and, in some instances, it was found that the Germans had uncovered new approaches to various technical problems. Typical of these approaches were developments in jet and rocket engines, guided missiles, and arrow-shaped vehicles for supersonic velocities; the 88-millimeter field gun and the machine gun with quickly replaceable barrel for use in ground warfare; and the Schnorkel breathing device to permit submarines to travel long distances under the sea to prevent risk of radar detection when surfaced.

In the field of electronics, the Germans had succeeded in developing and using a number of ideas which compared favorably with Allied developments. Such components as carbon-film resistors, metallized-paper capacitors, and metallized-ceramic coils were outstanding in providing lightweight, stable, easily adjusted equipment. Basic investigations in communication, navigation, and radar systems were conducted to provide solutions to specific problems in bombing, night flying, and operations at sea. Many of these ideas presently are being investigated for peacetime uses in United States, England, and France.

Recognition of the vital importance of electronics in modern warfare is an old story now, four years after the end of World War II. The terrifically increased tempo of modern battle on land and sea and in the air made absolutely essential the employment of new devices for the faster and more accurate control of military units and their weapons. The United States and England were fortunate in having leaders who recognized the important part that scientific methods and research must play if we were to win

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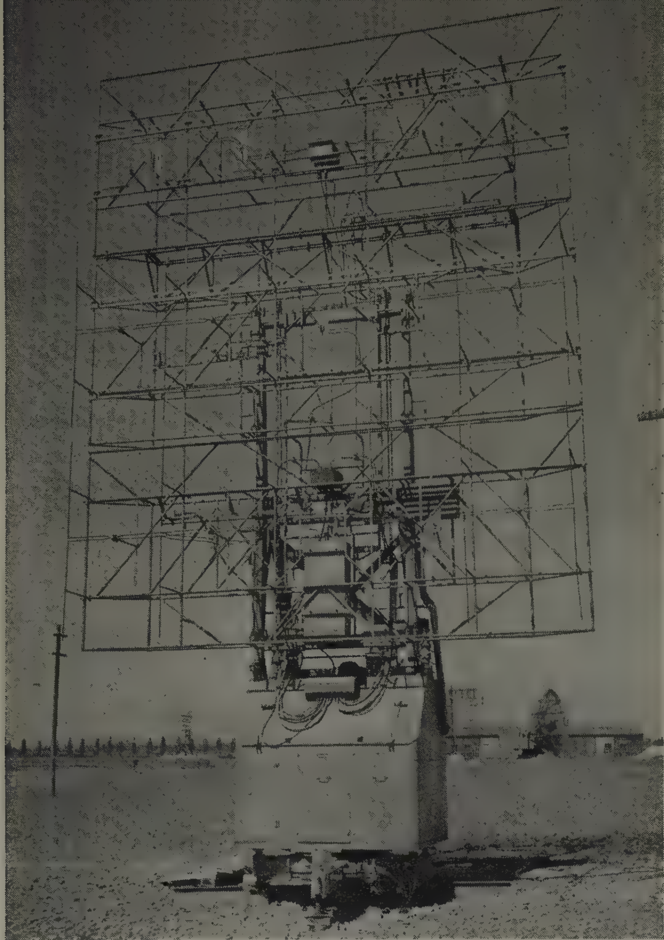


Figure 1 (left). The Freya radar was the most widely used long-range radar; this is the Limber Freya, for mobile use

Figure 2 (above). The Giant Wurzburg radar was designed for accurate short-range measurements

against our enemies. Money and skilled manpower were made available for organized technical development, even in the early stages of the war, and we were able to gain an edge on our enemies which they never overcame.

Manpower requirements necessarily are very great in any large-scale technical program. The Nazis at the beginning of the war had decided to rely on a short, rapidly fought conflict utilizing the shock power of highly mobile, well-equipped military units. To make available as much manpower as possible for the armed forces, German government policy after 1939 prevented the large-scale programming of basic electronic and physical research. Development work, in general, was frozen in order to standardize military equipment. Various individuals in the Luftwaffe and in scientific circles attempted to have this policy changed but it was not until a British aircraft containing microwave radar was shot down in January 1943, that the full import of the scientific situation was brought home to the Nazi leaders. As a result of this incident, Hitler personally ordered immediate priority given to electronic research and the Germans began a frantic effort to devise means of counteracting the Allied advances in radar and other electronic developments.

The most immediate result of this effort was a sudden surge of activity to find means of combating the jamming by the Allies of the German radars. The Nazi military technicians tried at least a dozen methods to fit their Freya and Wurzburg radars with attachments which would solve this problem. Concurrently, laboratory workers began work on components and equipments to operate in the microwave region of the frequency spectrum. By the end of the war so many projects were in various stages of completion that even the German government agencies in charge were having difficulty in keeping track of their own work.

The jamming methods employed by the Allies against German radars were of two types: electronic, in which a noise transmitter effectively blocked out the radar receiver; and multiple target jamming, in which a large number of metallic-foil strips (known to the Allies as "window"), dropped from aircraft, returned so many radar echoes as to confuse the enemy operator. Since it

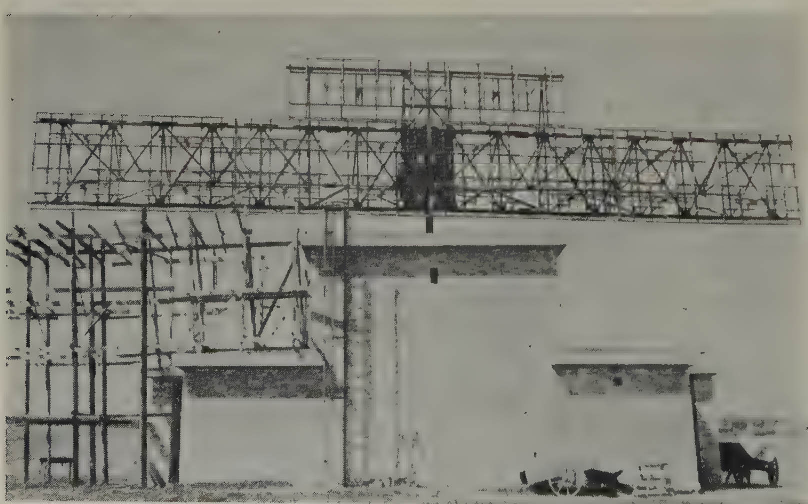


Figure 3. The Jagdschloss radar was designed as a permanent installation for providing ground control of fighter activities

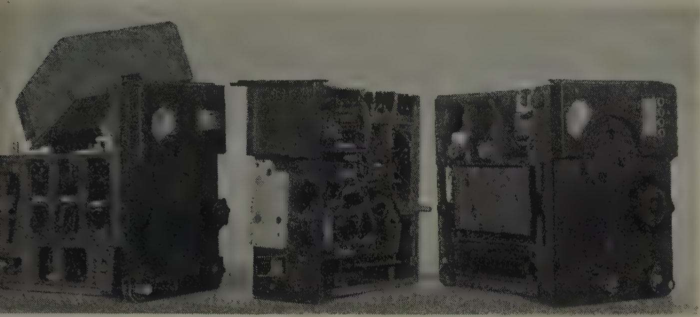


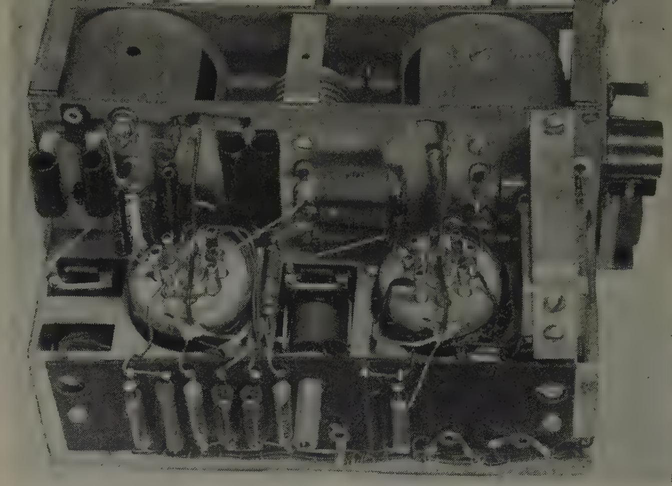
Figure 4 (top). The FuG 16ZY, a very-high-frequency aircraft radio, with the PV62, the universal test meter, plugged in

Figure 5 (below). Components of the FuG 16ZY aircraft radio including the receiver, modulator, and transmitter

has been calculated that the jamming methods employed by our Air Forces in Europe saved approximately 450 4-engined aircraft and crews, it is easy to realize the lengths to which the Germans would have gone to counter our jamming devices in order to increase their score of airplanes shot down. The cash value of these airplanes amounted to approximately $150,000,000, but in saving them it is necessary to remember the saving of several thousand lives of crew members, the savings in production man-hours in this country, and saving of training facilities for replacement crews. Consequently, it is no wonder that the Nazis were willing to tie up 90 per cent of their electronic engineers on jamming counter measures. However, they never quite caught up with the rapid Allied electronic advances, and most of their antijamming devices were obsolete before they could be placed in use. About a dozen different types of devices were employed and more were in development when peace was declared. The jamming war had grown to such proportions by the spring of 1945 that the Germans irrevocably were committed to a gigantic modification program affecting all of their radars, and they were unable to turn to the development and production of modern equipment which would have definitely provided a more satisfactory solution of their radar problems.

In their efforts to overcome the Allied lead in electronic research and development, the German scientists thoroughly explored the realms of radio, radar, infrared, proximity fuses, vacuum tubes, ceramics, components, and navigational devices; they all but succeeded in outdoing H. G. Wells with his scientific wonders when they revolutionized the weapons of modern warfare with the introduction of remotely guided and controlled weapons.

The illustrations of this article and the following descriptions give a picture of some of the German electronic equipment. Obviously, it would be impossible for one person to examine such a huge collection of data as was available at the end of World War II; therefore, full acknowledgment is made here of the work of the many hundreds of military and civilian technicians who were



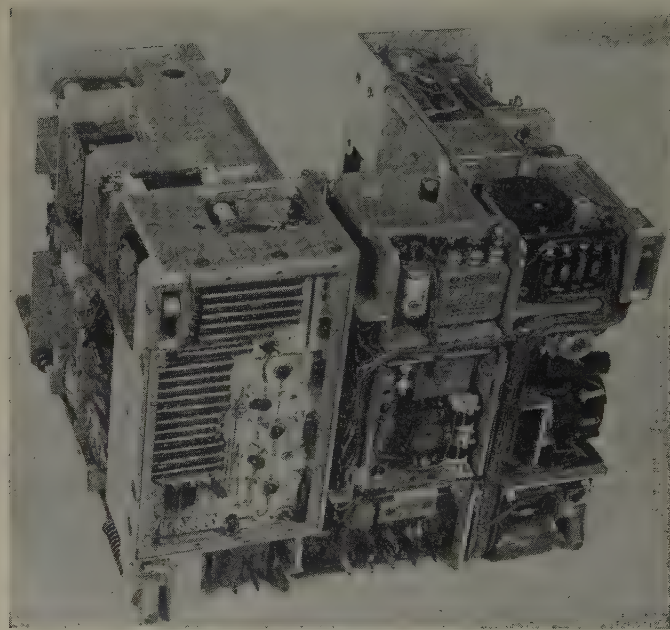


Figure 6 (top). The FuG 24 aircraft radio was designed for quick mass-production

Figure 7 (below). The Peil G 6 receiver was standard direction finding equipment for aircraft

Figure 8. A German very-high-frequency receiver for use at ground stations

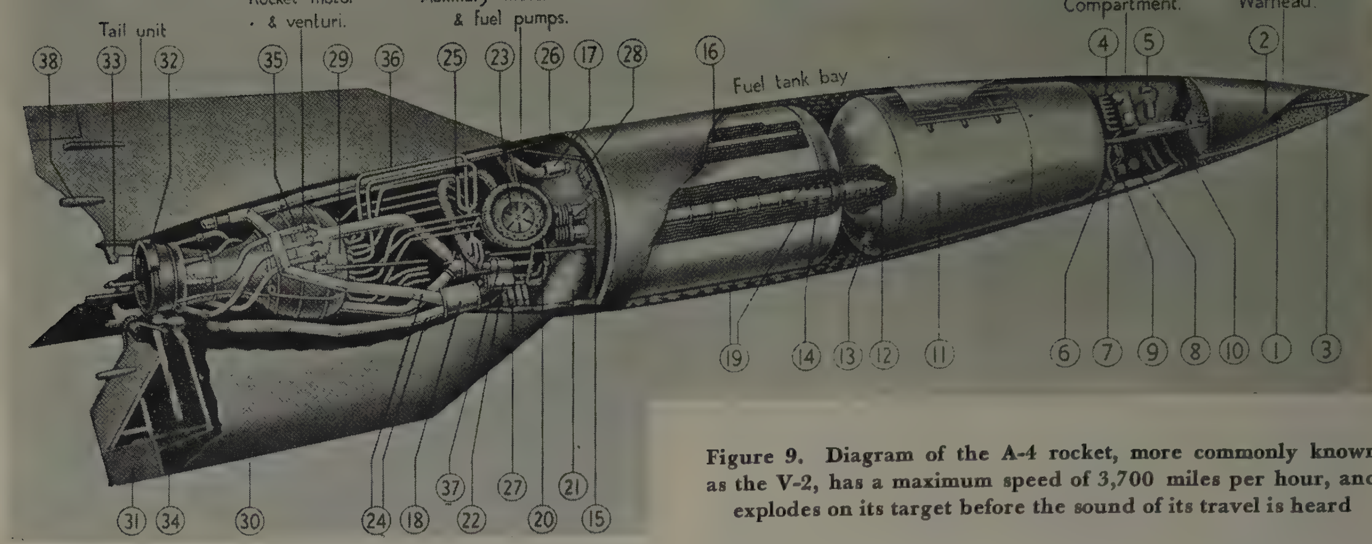


Figure 9. Diagram of the A-4 rocket, more commonly known as the V-2, has a maximum speed of 3,700 miles per hour, and explodes on its target before the sound of its travel is heard

1. *Alcohol tank pressuring pipe*
2. *Slinging point*
3. *Central exploder tube*
4. *Main distribution box and ground control plug*
5. *Alternator and regulator*
6. *Time switch*
7. *Alcohol fueling inlet*
8. *Air pressure gauge and hand control cock*
9. *Automatic pilot*
10. *Control amplifier*
11. *Alcohol tank*
12. *Outlet valve*
13. *Drainage valve*
14. *Alcohol delivery pipe*
15. *Oxygen fueling inlet*
16. *Stack pipe*
17. *Oxygen tank vent valve*
18. *Heat exchanger unit*
19. *Glass wool*
20. *Turbine*
21. *Hydrogen peroxide tank*
22. *Sodium permanganate tank*
23. *Oxygen and alcohol pumps*
24. *Turbine exhausts*
25. *Oxygen main valve*
26. *Braced steel frame*
27. *Compressed air bottles*
28. *Distribution box*
29. *Combustion chamber*
30. *Stabilizing fin*
31. *Outer rudder*
32. *Thrust ring*
33. *Carbon rudder*
34. *Servo motor*
35. *Alcohol feed pipes*
36. *Oxygen feed pipes*
37. *Auxiliary combustion chamber*
38. *Aerial supports*

responsible for investigation of German electronic industry.

Radar. Over a period of years, various German technicians had investigated the principle of radar; the experiments of Heinrich Hertz had first demonstrated this property in 1886. By 1939 a large number of the so-called Freya radars (Figure 1) were in operational use in Germany. With various modifications, this equipment remained the backbone of the German aircraft early warning system throughout the entire war. It operated at frequencies in the neighborhood of 125 megacycles. Two separate antenna arrays were used; the receiver array, on top, was exactly the same as the transmitter array with six vertically polarized, center-fed, full-wave dipoles.

The Wurzburg radar operated on a frequency of 560 megacycles and could measure heights (which the Freya could not) as well as provide more accurate range and bearing indication. The antenna system consisted of an offset rotating dipole (with secondary reflector) mounted in the center of a 118-inch parabolic reflector. Of particular interest was the provision of a common receiving and transmitting antenna circuit. The entire system could be rotated through 360 degrees, and the antenna parabola could be tilted through 90 degrees. To provide the higher accuracy and greater range required for ground control of Luftwaffe fighters, the standard Wurzburg *D* (the most widely used model of the Wurzburg) was modified in the form of the Giant Wurzburg (Wurzburg Riese)(Figure 2). This equipment utilized a 295-inch reflector for the antenna system which reduced the beam width to about half of that of the standard Wurzburg with a range increase of two to three times.

The Jagdschloss radar (Figure 3), which appeared in 1944, utilized the Freya components. Here, for the first time, the PPI (plan position indicator) principle was used in German equipment, with a 15-inch cathode-ray tube providing the panoramic display. This equipment was unique for its provision of means of transmitting the display signals over open wire lines for 20 miles.

Radio Equipment. The *FuG 16* was the standard German very-high-frequency aircraft equipment; the receiver

Figure 10 (left). The Enzian antiaircraft rocket mounted on launching vamp

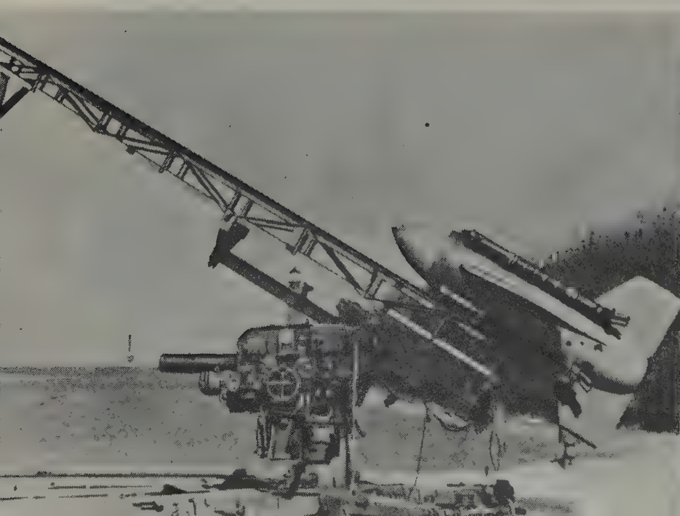


Figure 11 (right). The X-4 wire-controlled missile in mounted position under an aircraft wing

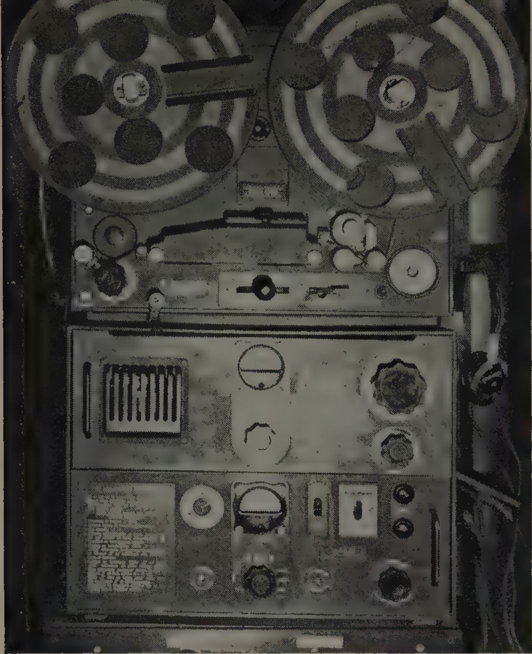


Figure 12 (left). The Tonschreiber magnetic tape recorder was a portable piece of equipment designed for office dictation and military use

Figure 13 (right, above). The iron-core flush-mounted antenna for the Piel G 6 aircraft receiver

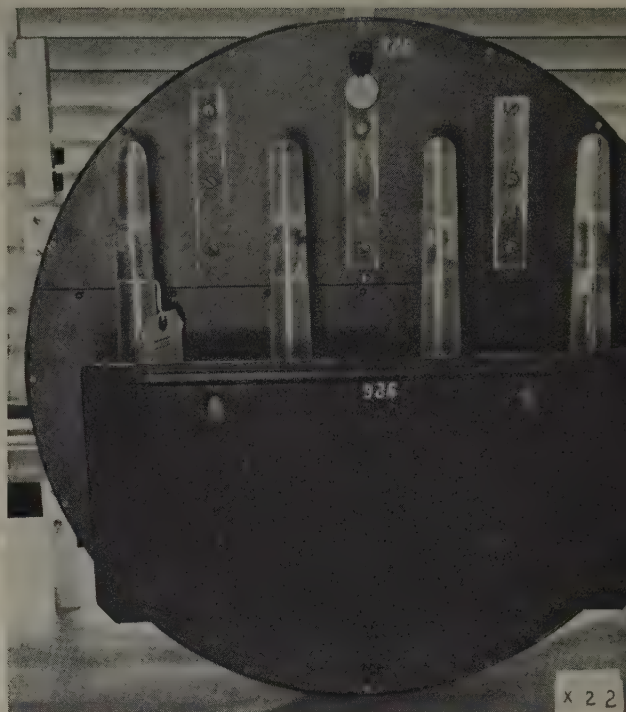


Figure 14 (right, below). The dielectric antenna was one of the few modern German air-borne antennas

component proved to be one of the finest in its frequency range used by either the Allied or Axis forces. Although it was not crystal-controlled, it was extremely selective and stable, adjacent channels being separated by only 50 kc. Temperature variations of ±50 degrees centigrade and supply voltage fluctuations between 22 and 29 volts changed the transmitter frequency by less than 0.2 of one per cent. The *FuG 16* subtypes operated in various portions of a band of frequencies from 38 to 48 megacycles; the *ZY* model was the latest of the revisions of this equipment (Figures 4 and 5). By using a *PV62* universal test meter, simple tests would isolate trouble to one of the three major components for quick replacement.

The Luftwaffe planned eventually to go over to a mass-produced "quick and dirty" aircraft radio set for use in its jet fighter. The new equipment, the *FuG 24* (Figure 6), weighed only 35 pounds, including the power supply. Its frequency range (37–50 megacycles) included the frequency ranges of both the *FuG 16* and *FuG 17*. The receiver was a 6-tube superheterodyne with input sensitivity of about 10 microvolts; the transmitter was a simple 3-tube 2-watt affair and was preset on the ground to two frequencies which could be selected by a push button. Tuning was accomplished with sliding contacts on coils wound with silver-plated wire.

The Peil *G 6* receiver (Figure 7), the standard direction finding equipment for aircraft, is typical of much of the better type of German set construction; unit assembly and a rigid wiring layout give high stability and generally good performance. The die-cast magnesium chassis provided excellent shielding as well as solidity of construction.

A typical German very-high-frequency receiver for use at ground stations (Figure 8) shows the heavy, solid construction which made such sets suitable for rugged field use. Similar construction in most German equipments gave exceptional reliability and few maintenance difficulties. The problems of the operator and service man were anticipated by the manufacturer. Such things as large convenient switches and knobs and easily accessible tubes and parts were standard items of construction. Color coding of the various frequency band designations was helpful in quick band switching.

Rockets. A series of self-propelled missiles and rockets was the result of the Nazi attempt to overcome the advantages held by the Allies in the air. Most of these missiles depended for their stability and guidance on electric and electronic systems which controlled direction and range. Two developments, the so-called *V-1* and *V-2* rockets (Figure 9), fell in the class of major weapons of war. The first extensive use of missiles against major targets began in June 1944, when the first *V-1* or buzz bomb fell on London. A total of about 8,200 were launched against England; by September 1944, Allied advances on the continent had forced the German launching sites beyond the 150-mile range of the buzz bomb and the attacks ceased. Then began the era of the *V-2* rocket; the important advantage of the *V-2* type of missile lay principally in its tremendous speed, faster than that of sound. Consequently, there was no satisfactory method of warning since having a maximum speed of 3,700 miles per hour, it exploded on the target before the sound of its travel through the air was heard. The missile carried one ton of explosives and weighed over 12 tons at take-off. Two methods of control were used, one being an integrating accelerometer and the other being a form of radio control. The control actually was exercised only during the first part of the rocket flight to cut off the fuel at what was termed the "brennschluss" which was the point in the trajectory at which the powered part of the rocket travel stopped.

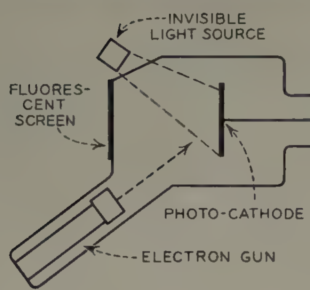


Figure 15. The Krawinkel image storage tube was one of the most interesting cathode-ray tube developments

In addition, several other missiles were well on the way to operational use. Among these were the Enzian (Figure 10), a 17-foot antiaircraft missile with 990 pounds of explosive; the Wasserfall, a 26-foot missile similar to the *V-2* but intended for use against aircraft; and the Rheintochter, an antiaircraft device which travelled at 1,100 miles per hour and carried 330 pounds of explosive. All of these missiles were controlled by radio and, in addition, methods of radar tracking were employed. The *X-4* (Figure 11) was a unique weapon which was controlled by thin wires between the missile and the aircraft from which it was fired. The wire signal circuit prevented jamming of the control system.

Magnetic Tape Recorders. One radically new German idea in the field of electronics was the development of several types of magnetic sound recorders using a cellulose or plastic tape with a layer or impregnation of iron oxide. The best known recorders were the Tonschreiber (Figure 12) and the Magnetophon. The Tonschreiber was designed for office dictation and military use; the fidelity was about that expected from a standard piece of communications equipment, peaking between 2,000 and 5,000 cycles per second. The tape was sufficiently thin so that full size reels would allow steady recording for 30 to 45 minutes; the tape speed could be adjusted for any value between 4 inches and 48 inches per second. The Magnetophon was a high-quality recorder set up in a permanent manner, and used high-frequency erasing and recording methods which improved the quality of the recordings. Three types of tape were used, the earliest commercial tape being a cellulose-acetate material with a layer of 0.01 to 0.02 millimeter of magnetite, a form of iron oxide. Later tapes were made of Luvitherm, a type of polyvinyl chloride, in which the magnetic material was impregnated. Another development was a method for putting a layer of magnetite on the surface of the Luvitherm.

Antennas. The metal lens antenna simulates an optical system by utilizing a group of wave guides as the elements of the high-frequency lens. The picture at the beginning of the article shows details of the wave-guide groups of an antenna for a 5.12-centimeter wave length. Although the expense of this type of antenna was rather high, the accuracy of the results obtained by mathematical application of optical lens formulas was excellent. Experimental work was started on this antenna in 1937, but it had not reached the status of wide-scale use at the end of the war.

The iron-core flush-mounted antenna (Figure 13) was a unique feature of the Peil *G 6* direction finding receiver. This antenna had an iron core and was mounted inside a container which was sunk flush with the aircraft surface and covered with a plastic window. This arrangement gave about 85 per cent of the efficiency of the conventional German external loop antenna but had the tremendous advantage of negligible air resistance. The development of this antenna was based almost entirely on experimental determination of the optimum ratio of weight of the iron core to antenna signal-voltage output. This optimum weight was found to be approximately $6^1/_2$ pounds.

When the first Allied air-borne centimetric radar was captured in a crashed aircraft, the resulting crisis in German military circles created a minor scientific furor which lasted until the end of the war. The principal result of the centimeter scramble, as far as air-borne equipment was concerned, was an equipment known as the "Berlin." An interesting part of the set was the multielement collinear dielectric antenna (Figure 14); it operates at a speed of 400 rpm. It worked in a manner similar to a leaky wave guide; the high-rotational rate obviated, to some extent, possibilities of jamming. The dielectric elements

Figure 16 (left). Cathode-ray tubes with short gun lengths

Figure 17 (right). A 2-gun cathode-ray tube

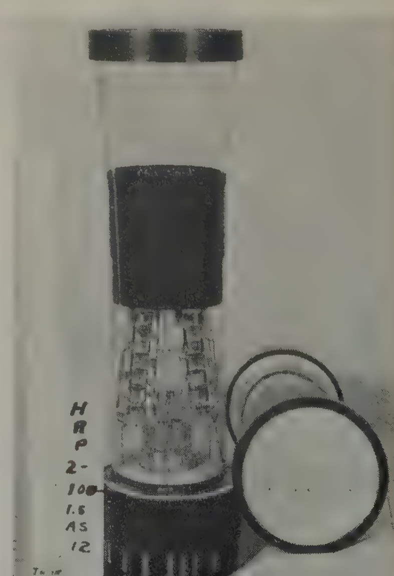


Figure 18. Coils were made by depositing metallized coatings on ribs of ceramic forms

were mounted either parallel to or normal to the axis of rotation depending on the particular design of the antenna system. The system had the advantages of light weight, small size, and lack of complication, and showed promise for efficient use with high-speed aircraft.

Storage Tubes. In an attempt to overcome the effects of the use of "window" for jamming, a 2-color cathode-ray tube was tried using long after-glow and short after-glow screens of different colors on the same tube. The long after-glow screen produced a greenish color whereas the short after-glow screen showed a reddish color. Thus, a moving target such as an aircraft would produce a small "blip" with a red leading edge (in the direction of motion) with a greenish tail. A nonmoving target, such as "window," would produce only a long after-glow with the characteristic greenish color. To improve certain functions of standard cathode-ray tubes, a number of so-called storage tubes were developed. Three well-known ones were the Blauschrift, the Mocos, and the Krawinkel tubes (Figure 15). The idea was to obtain a device capable of storing an image or a signal for a long period of time and then allowing it to be utilized later. The important element in the Krawinkel storage tube was the photo-cathode surface containing a large number of minute quartz particles, which acted as capacitors; when the cathode surface was scanned by an intensity modulated beam from the electron gun, an electrostatic image was produced utilizing the charge on each quartz particle as a point element of the electrostatic image. The charged quartz particles acted as a grid when the photo-cathode was illuminated by an invisible light source and the image thus produced by the photo-cathode could be magnetically focussed on the viewing screen.

Cathode-Ray Tubes. In general, German cathode-ray tubes were similar to those in use in America and England. However, emphasis was placed on special developments for specific uses. For example, cathode-ray tubes for use in air-borne radar equipment and other small equipment were made with very short gun lengths (Figure 16) resulting in a comparatively low ratio between face width and over-all tube length. In addition to a better space factor for most uses, this design resulted in relative freedom from beam dispersion and increase in deflection sensitivity. The gun structures of all German cathode-ray tubes were masterpieces of fine workmanship to very close tolerances. Double and triple gun tubes (Figure 17) were fairly common both before and during the war, and one company, by the end of the conflict, was experimenting with tubes containing six guns.

Components. Ceramics were used for a variety of purposes; one of these uses was as a base for thin carbon film resistors. Carbon was deposited on the ceramic rod or tube by cracking a hydrocarbon at high temperature and utilizing the resulting thin carbon coating as a resistance. The value of this resistance was adjusted by cutting a spiral through the coating down the length of the tube; the cutting of the spiral was done by hand. These resistors were made in all of the standard values, and had a great degree of precision and stability.

Inductances with ultrahigh stability were made by depositing metallized coatings on standard ceramic forms, either in grooves or on raised ribs (Figure 18). Various metals were used including silver, copper, zinc, nickel, cadmium, and iron. Complete oscillator circuits were built up using metallized ceramic parts; it was claimed that these arrangements approached the stability of crystal circuits. The low coefficient of expansion of the ceramic reduced temperature effects to a minimum.

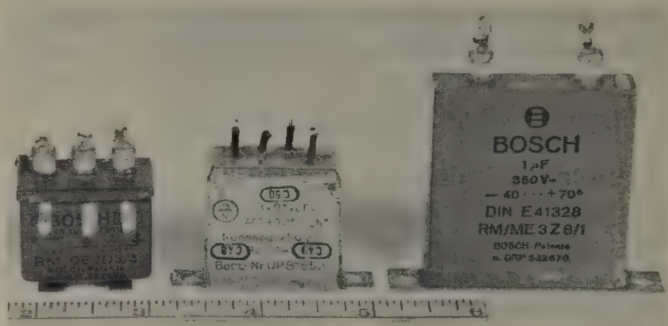


Figure 19. Two metallized paper-type capacitors are shown on either side of a standard capacitor for comparison of size and voltage ratings

Because of the shortage of natural mica, methods of manufacturing artificial mica were in the process of development. This mica had all the physical and electrical characteristics of natural mica and, in addition, was moisture-free. Metallized-paper capacitors (Figure 19) developed by the Germans occupied only about two-thirds of the volume of the standard metal foil capacitors for the same electrical characteristics. The capacitors were wound with paper on which vaporized zinc metal had been deposited. The thickness of the metallic layer was only 0.1 micron. The insulation value of the paper used was increased by about 50 per cent by the application of a lacquer coating of about 0.5 micron in thickness. Experiments had also been made using a plastic substitute for the paper. These capacitors, within the lower voltage ranges, were entirely satisfactory and were used extensively.

Electrical Analogue of a 2-Stage Rototrol

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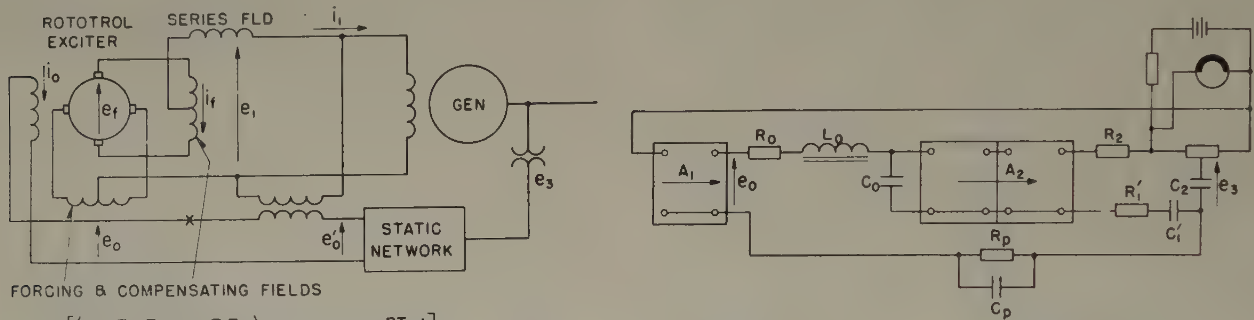
THE HIGH-CAPACITY 2-stage Rototrol shows great promise as the principal element in large generator excitation systems. Figure 1 illustrates a voltage-regulating system. The main unit is a 70,000-kva 3,600-rpm turbogenerator. The excitation is supplied by a 200-kw 2-stage Rototrol. The static network consists of a saturating reactor, the impedance of which is compared automatically with a capacitive reactance of constant value. As the generator voltage increases, the reactance of the saturating reactor decreases until at the regulated voltage, the reactances of both elements are equal. In this manner, a reference point is obtained. The output of the static network is rectified by dry-type rectifiers and introduced into the control field of the Rototrol.

The transient performance and the stability are radically affected by damping transformers. These elements, which are physically small and comparatively inexpensive, are of primary importance in determining the system performance. The determination of the optimum damping-transformer parameters is the purpose of this investigation.

The Anacom, electrical analogue computer, was used. The method of solution was as follows: The system analogue was determined by inspection. A trial analogy having been produced, its differential equation was written and compared with the differential equations of the actual system. If the equations of the analogue circuits are identical to those of the actual system, the analogy is acceptable. Initial conditions simulating change in reference and load were produced repetitively by a switch and battery combination. The performance of the system was measured by a cathode-ray oscillograph.

In the analogy shown in Figure 1, R_2 and C_2 represent the generator delay; R_0, L_0, and C_0 represent the Rototrol delay; C_1' and R_1' represent the self-energizing effect of the series field; and R_p and C_p represent the damping transformer with primary delay. Amplifiers supply system amplification $A_1 A_2$.



$$e_0 = B\left[\left(1+p\left(\frac{T_0+T_f}{1+a_f}\right)+p^2\left(\frac{T_0T_f}{1+a_f}\right)\right)(1+pT_2)-a_1\left(1+\frac{pT_0}{1+a_f}\right)\right]e_3 \qquad (1a)$$

$$e_0 = -A\left(1+p\frac{t_1(1+pT_2)}{(1+pT_{p1})}\right)e_3 \qquad (2a)$$

WHERE

T_0 = TIME CONSTANT OF CONTROL FIELD
T_f = " " " FORCING "
T_2 = " " " GENERATOR
t_1 = " " " DAMPING TRANSFORMER = $\frac{M}{R_p}B'$
T_{p1} = " " " " TRANS. PRIMARY
a_f = PER UNIT EFFECT OF ARMATURE REACTION
a_1 = " " SELF ENERGIZING EFFECT OF ROTOTROL

$$\left.\begin{aligned} A &= -\frac{\Delta e_0'}{\Delta e_3}\\ B &= \frac{\Delta e_0}{\Delta e_3}\\ B' &= \frac{\Delta e_1}{\Delta e_0'}\end{aligned}\right\}\text{SERIES FIELD NOT CONNECTED, SYSTEM OPEN AT POINT "X"}$$

$$e_0 = \left(\frac{1}{A_2}\right)\left[(1+pR_0C_0+p^2L_0C_0)(1+pC_2R_2)-\left(\frac{A_2C_2}{C_1'}\right)(1+pR_1'C_1')\right]e_3 \qquad (1b)$$

$$e_0 = -A_1\left(1+\frac{pR_pC_0(1+pC_2R_2)}{A_2(1+pR_pC_p)}\right)e_3 \qquad (2b)$$

WHERE

$R_0C_0 \equiv \frac{T_0+T_f}{1+a_f}$ $\qquad \frac{R_pC_0}{A_2} \equiv t_1$

$L_0C_0 \equiv \frac{T_0T_f}{1+a_f}$ $\qquad A_1 \equiv A$

$C_2R_2 \equiv T_2$ $\qquad A_2 \equiv \frac{1}{B}$

$R_pC_p \equiv T_{p1}$ $\qquad \frac{A_2C_2}{C_1'} \equiv a_1$

Figure 1. Two-stage Rototrol regulating system

Schematic diagram (left); analogue (right)

It has been observed that the generator-voltage damping transformer with negligible primary delay is more effective than the same transformer operating as an exciter-voltage damping transformer. It was believed that an exciter-voltage damping transformer having an appreciable primary delay might approach the performance of the generator damping transformer.

The response obtained with optimum damping-transformer parameters shows that the optimum value of primary delay is about 30 per cent of the generator time constant. Wide variations in performance indicate that the damping-transformer parameters are an important factor in the determination of voltage-regulator system behavior under diverse conditions.

Digest of paper 49-8, "The Transient Behavior of the 2-Stage Rototrol Main Exciter Voltage Regulating System as Determined by Electrical Analogy," recommended by the AIEE power generation and computing devices committees and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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The Heat Pump as a Residential Electric Load

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THE USE of electricity in one form or another for heating homes has been considered off and on over a span of many years throughout the electrical utility industry. It is generally conceded, however, that, at the existing state of the art, electricity cannot compete in cost for house heating, on a direct energy conversion basis, with other fuels, such as coal, oil, or gas.

Table I illustrates this point, using a home requiring 100,000,000 Btu during an average heating season at fuel prices now generally prevailing in a large metropolitan area of the Middle Atlantic states. The price of electricity is assumed at $2^1/_2$ cents per kilowatt-hour to approximate the cost of supplying this service under the low annual load factor of the house heating load. The comparison is confined to costs applicable to fuel only. These numbers do not purport to represent a complete comparison of the total costs of heating with various fuels, since investment and maintenance costs, and cost equivalents of many intangibles have been omitted to simplify the illustration.

Since, for a given method of electricity production and distribution, its cost per kilowatt-hour depends primarily upon the annual diversified load factor of the load served, and since the annual diversified load factor of the house-heating load is fixed largely by prevailing climatic conditions of the territory, it becomes evident that if it were possible to reduce the quantity of electricity required to do the job of house heating, say, by four times, then the total seasonal cost of electricity for heating would become as low as that of gas, the nearest high-grade house-heating service.

This is where the heat pump fits into the picture. It can be used to multiply the effectiveness of electricity for heating purposes, and thus make practicable the economical supply of energy for residential house heating by electrical utilities, because, from thermodynamic considerations, a heat pump can be made to deliver from three to five kilowatt-hours in equivalent heat for every one kilowatt-hour required for its operation.

Table I. Comparison of Cost Applicable to Fuel for Heating a Home Which Requires 100,000,000 Btu During a Heating Season From September to May

	Electric Resistance Heating	Manufactured Gas	Fuel Oil	Coal
1. Kind of units	Kilowatt-hours	Thousand cubic feet	Gallons	Net tons
2. Btu per unit employed	3,415	520,000	140,000	24×10^6
3. Efficiency	100 per cent	75 per cent	65 per cent	50 per cent
4. Useful heat delivered to house per unit Btu	3,415	390,000	91,000	12×10^6
5. Units required to heat house	29,283	256	1,099	8.33
6. Cost applicable to fuel				
a. Price per unit	$2^1/_2$ cents	70 cents	10 cents	$15
b. Cost of fuel	$732	$179	$110	$125
c. Cost of electricity for auxiliaries			$ 8	
d. Total cost	$732	$179	$118	$125
7. Approximate relation to cost of electric resistance heating	1	$^1/_4$	$^1/_6$	$^1/_6$

The heat pump possesses the thermodynamic ability to remove the inherent economic handicaps present in electric-resistance-type house heating. But to make it a commercial reality, within the reach of a large number of homes, it requires a substantial amount of additional research on the economical methods of utilizing available heat sources and on the engineering, design, and operation of compressor-motor assemblies, refrigerants, accessory equipment, and methods of heat distribution.

The electric load of an all-electrical residential customer with a heat pump will be very large in comparison with the load of present-day average residential customers. The potential magnitude of this load and the difference in its load characteristics from those of the present-day residential class, deserve careful study by electrical utilities and manufacturers of power-distribution, substation, transmission, and production systems.

By and large, within the practical range of probable heat-pump saturations for residential house heating in the order of 20 per cent, the electric load of this device in the northern and middle temperature zones of this country neither will improve nor affect adversely (to any large extent) the annual load factor of the residential class of service. But for very large saturations of the device, substantial reductions in the annual load factor of this class of service can be expected, because of the inherently low annual load factor of the heat-pump load.

To attain the optimum in the over-all competitive ability of the heat pump in regard to other methods of house heating, all efforts must be directed toward obtaining for this device the highest efficiency of performance, the highest reliability of operation, the lowest "first cost," and the minimum of undesirable electrical features such as high-starting currents, low power factors, and high demands.

The heat pump load carries with it the ability to improve the economic significance of the residential summer air-conditioning load which, by itself, is not desirable in large quantities because of its low annual load factor. A proper implementation of the year-round heat-pump load with additional summer air-conditioning load for customers with conventional heating systems will tend to improve the over-all economic significance of the combined residential heating and cooling loads.

Digest of paper **49-1**, "The Heat Pump—Its Significance as a Potential Residential Electric Load," recommended by the AIEE domestic and commercial applications committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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The Temperature Rise of Buried Conductors

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IN THE CALCULATION of the temperatures attained by underground cable systems, the Kennelly formula for calculating that portion of the temperature rise occurring in the earth was developed in 1893. Various objections since have been raised to the use of this formula, chiefly because it has been believed that it is contradicted by experimental evidence.

The Kennelly formula represents the ultimate temperature rise of a horizontal, cylindrical, thermal radiator buried in the earth above ambient earth temperature at the same depth in terms of the constant heat loss per unit length Q, the thermal resistivity of the earth ρ, the depth of the radiator L, and its radius R.

$$\Delta T = Q\frac{\rho}{2\pi}\log_e\frac{L+\sqrt{L^2-R^2}}{R} \tag{1}$$

The formula is applicable to cables and pipe-type cable systems buried directly in the ground and also to cable-in-duct systems by formulating an equivalent radius for use in the formula from the geometry of the duct system.

As the formula represents in effect the temperature difference between two points at the same depth, it is independent of the seasonal vertical temperature gradients existing in the earth, and the direction of heat flow from the cable system which of course is dependent upon these vertical gradients.

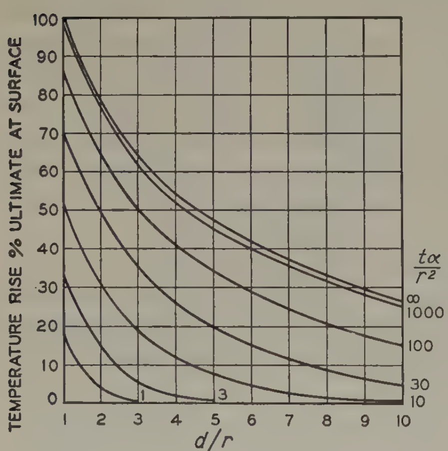

Figure 1. Temperature rise of points in the horizontal plane of a cylindrical radiator as a function of time

d=distance from a point in the heat field to the thermal center of the radiator; r=radius of radiator; t=time; α=thermal diffusivity

The very long time which would be required to attain the steady-state heat-flow conditions represented by the Kennelly formula is a factor which is almost impractical to reproduce in the field. Consequently, observations made in the field with cable systems will indicate apparent thermal resistivities for the earth which are too low, if not corrected.

Figure 1 shows the relative temperature rises of points in the horizontal plane through the center of a cylindrical radiator buried to a depth ten times its radii in terms of the ultimate temperature rise at the surface and for various values of $t\alpha/r^2$. From this it will be seen that during the transient period at a given time, the relative temperature rise of a given point in terms of the corresponding rise at the surface of the radiator is less than that which will obtain after infinite time. In other words the horizontal temperature gradient will be steeper than indicated by equation 1. This fact has been observed during tests.

Also, in comparing these field values of thermal resistivities with those resulting from laboratory tests made on samples of the same soil, the method of sampling and conducting the tests must be such as to yield values representative of those actually pertaining in the field. Otherwise, fictitious and too high values of thermal resistivity will be obtained in the laboratory.

The thermal resistivity of the earth, being a complicated function of the soil structure and moisture content, will vary widely with the location and in some degree with the season of the year. In fact, the resistivity of the earth in the vicinity of the cable installation may not be uniform as presupposed by the formula. A contributing factor to this nonuniformity is the inherent migration of moisture in the soil in the direction of heat flow.

A practical solution of the problem may be effected by the use of an over-all equivalent thermal resistivity which is momentarily constant but which, of course, will vary in some degree seasonally. This effective thermal resistivity may be back-calculated by suitably controlled tests on an actual cable installation, or may be measured more conveniently by the use of auxiliary spherical or short cylindrical test radiators. These radiators are subject to mathematical treatment by which equations for thermal resistivity in terms of temperature rise, heat loss and basic geometry may be derived, and they have the advantage of requiring relatively little excavation work and relatively short times to reach the substantially ultimate temperature rise that is required for the correct application of the Kennelly formula.

In conclusion, it is believed that the Kennelly formula may be used to calculate the ultimate temperature rise of cable systems with sufficient accuracy provided that the effective thermal resistivity of the earth which is an inherent part of the formula is properly determined for the particular field conditions pertaining. The apparent discrepancies which have challenged its validity in this application have been due to a misunderstanding of exactly what it represents and to the use of inapplicable measured values of thermal resistivity.

Digest of paper 49-2, "The Temperature Rise of Buried Cables and Pipes," recommended by the AIEE insulated conductors committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Industry's Co-operation in Graduate Education

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Based upon experience to date, there is every reason to believe that an adequate and satisfactory method of conducting graduate technical education can be accomplished by taking the courses off the campus to the student who is already in industry. This article, which describes two such programs carried out by the Illinois Institute of Technology, is the second to be published of a group of papers presented at a symposium on education held during the recent winter meeting; the first paper in the series appeared in the April issue.[1]

THE IDEA has been prevalent in the minds of many educators that true education can occur only in the sacred halls of learning on college campuses, and that classes, seminars, research work, and private study carried on elsewhere cannot give rise to anything but an inferior result which should not be given college credit or considered more than vocational education. However, in recent years, many engineers, scientists, and even educators, have subscribed to the view that education is where you find it, and that good results can be obtained in other ways. Before reaching a conclusion on this question, let us examine a little more in detail what we mean by true education, and in particular by graduate education. To a very large extent, the area of graduate work is the area of specialization, in which subjects of particular interest are given special attention. Therefore, although general education and liberal studies are important, for the student in the scientific and engineering fields graduate work is concentrated for the most part in specialized fields which, for any individual student, are relatively limited in scope, but never in depth of penetration. In this area it seems to the writer that true education is characterized by concentration on the questions "why" and "how" things do happen, or may be made to happen. Basic principles must be studied more carefully, and the range of their application and their limitations more carefully explored and understood. The principles of analysis, as presented by physical sciences and mathematics, must be developed and applied.

THE SCIENTIFIC METHOD

Perhaps the foregoing description of education could be stated in another way as the development of the "scientific method." The scientific method may be described as the method of attack which starts with a careful statement of the problem, and makes a study of the background from which it arose; the previous literature of the subject; the contributions of other investigators; the development of possible theories, hypotheses, and processes with which to attack the problem; the verification or revision of these by analysis, experiment, or both; and finally the development of laws, principles, or conclusions. In the carrying out of the process described, the student not only proceeds to more complex problems, but he also must develop a better understanding of the basic laws of the science with which he is concerned, in order that the incorrect, the trivial, or the irrelevant may be discarded.

In developing the ability of the student to apply such methods, it is necessary to make a study of what has been done previously, and to follow the lead of the great scientists of the past. However, in order to fix principles and to develop the power to use them, it is necessary to study applications of principles to apparatus, systems, or processes. Thus, a student actually may obtain great benefit from a study of existing apparatus and the principles upon which it operates, if attention is focused upon the analysis of the machine in accordance with the basic laws, rather than upon the particular dimensions or arrangements which have been found convenient, without comprehensive analysis to show that these are the most satisfactory proportions from the standpoint of efficiency, performance, or cost. For example, a course described as "radio receiver design" might be, on the one hand, an exposition of the design processes of a particular design department, accompanied by empirical rules and handbook processes, or, on the other hand, a thorough and comprehensive treatment of the principles of radio circuits which are needed in receivers. In accordance with the thesis described, the first might be particularly valuable to the company for the training of apprentice engineers, but hardly would be classed as graduate education in the sense indicated here. The latter, however, certainly would contribute to the graduate education of a physicist or engineer whose field was electricity, particularly in the range of high frequency. Thus, the real criterion as to whether a particular subject or course contributes to scientific education depends at least as much, if not more, on the method of treatment and the method of teaching than upon the actual subjects treated.

With this background, it is easy to see that many courses established off college campuses, and perhaps also too many on college campuses, which are devoted primarily to a study of the current design and application of products, in order to familiarize the younger engineer with the methods in use, and to make it easier for him to take his proper place within the company organization, are not truly educational in the scientific sense. The objection to courses of this type, from the standpoint of education and

Full text of a conference paper, "Industry's Co-operation in Graduate Education," presented at the session on "Industry's Active Part in Education" held during the AIEE winter general meeting in New York, N. Y., January 31–February 4, 1949.

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particularly graduate education, is not that these courses are not valuable in themselves, but that they do not improve the power of the student to analyze new problems not solved before, and to develop new and improved devices which are soundly conceived, properly analyzed, and clearly represent important improvements.

The establishment of research laboratories by industries has done much to change the ideas of the people responsible for off-campus training, because research of itself must be based upon the development and application of the scientific method. A study of current practices in the business of an industrial concern sometimes may be the very worst way for a research engineer to seek basic improvements. There is too much danger that he will accept previous conclusions without adequate examination, and proper re-evaluation. Acting on this principle, many industries have established their research laboratories at locations somewhat remote from the production facilities, so that independence of thought and action on the part of the research personnel is fostered rather than discouraged. As more companies develop and staff their research laboratories, the demand for further training of a basic and fundamental character that can be described as true graduate education has developed in many locations.

EDUCATION IN INDUSTRY

To meet such needs as this, quite a few industrial companies have undertaken to provide educational opportunities for their employees to study advanced subjects and to obtain advanced degrees. These plans have taken many forms, but most of them can be described as fellowship plans, research grants, and part-time graduate programs. For many years, forward-looking industries have established fellowships at the leading educational institutions which provide for graduate study on the part of recent college graduates, or in some cases, for employees of the company who wish to return to college. In this way, the interest of the company in advanced training is indicated clearly, and students with an interest in further study are encouraged to take graduate training, either through the help of the fellowships or otherwise, and then to seek positions with those companies that definitely have indicated that they place a high value on the greater competence which comes with advanced study. Research grants operate in a similar fashion to help the colleges and universities develop their research programs so that their graduate staffs are more competent and better able to provide the training sought by graduate students. However, such programs as these are of benefit only to a limited number of students at any one time and do not meet the broader problem of more advanced training for the large group already in the company employ. To meet this problem, many companies now are helping and encouraging their employees to undertake part-time graduate programs in the evenings at nearby institutions, or if adequate opportunities are not available, to set up special classes within the plant. To ensure that these programs remain truly educational in character, co-operative arrangements have been worked out in many instances with neighboring educational institutions to supervise the educational phases of the plan and in some instance to grant academic credit for the work done. It is the contention of the writer that such programs, properly conceived and properly executed, can contribute immeasurably to the graduate education of the country.

Upon completion of the usual 4-year program for the bachelor's degree, a large percentage of students feel the immediate need for practical experience in spite of a desire for more advanced training. In fact, college professors often advise their students to enter industry for two or three years before returning to college for graduate study. In that period, the young engineer or scientist frequently accumulates responsibilities that make his return to college financially impractical. He also finds an opportunity for usefulness in industry that he is loath to terminate. Graduate study on a part-time basis arranged concurrently with industrial experience not only meets the need of young scientists and engineers, but is often a richer educational experience than further full-time attendance at college.

In criticizing such plans, those who oppose granting full academic credit for courses in such programs often point out that the student does not have access to the laboratories and libraries of the college when courses are conducted off-campus. If, however, the program is arranged in full co-operation with the industrial company, the laboratories of the company become an equally good training ground as that of the college laboratories, and in some instances, may be far better because of the ability of industry to provide more adequate laboratory facilities in specialized fields than can any college or university. So far as library work is concerned, it must be realized that graduate work is largely specialized, and that reference material is largely limited to special fields. In these special fields, the libraries established by industrial companies for the use of their engineers and scientists readily may be fully the equal of the college libraries in these same fields. If not, this difficulty can be remedied to a degree comparable with that of many institutions by a relatively small outlay for added library facilities.

If such courses as these are to be recognized as worthy of graduate credit, it seems to the writer that the most important element is the selection of the teachers who will handle these courses, to make sure that they have the desired attitude, and that the courses are conducted along suitable lines. In so far as possible, it is desirable of course that the same staff teach these courses when given off-campus that teach the same or similar courses when given on the campus. When this is done, and when suitable laboratory and library facilities are available, certainly such courses will not differ greatly from campus courses, and on the average will be no better or no worse than the corresponding campus courses. However, it is not always possible to utilize regular campus professors for all courses in such programs, and in these instances the choice of the best instructor involves a careful consideration of the training and educational experience, as well as the attitude, of the instructor selected. However, with suitable care and supervision, it is the writer's belief that instruction fully worthy of graduate college credit can be and should be obtained. In every such program, however, a substantial percentage of instructors should be regular members of the college faculty who travel to the off-campus locations to give these courses, to advise students,

and to consult with students regarding possible research programs which may be undertaken for research credit and the development of a possible thesis. When these safeguards are maintained, off-campus programs of this sort can be conducted at the true graduate level, and there should be no hesitancy in giving full graduate credit for them. In any case, whatever difficulties may arise, the same difficulties are present on the campus, although to perhaps a slightly lesser degree. When both industry and the colleges are aware of the problems, and approach them together, the problems can be fully surmounted, and adequate educational programs can be developed which bring to industry educational opportunities not possible otherwise.

ILLINOIS INSTITUTE PROGRAMS

To illustrate the foregoing principles, a brief description of two such programs as conducted by Illinois Institute of Technology may be helpful. Illinois Institute of Technology is located in the heart of Chicago, where it is accessible to the citizens of a large industrial area. As a consequence, a combined day and evening graduate program has been developed, which offers opportunities for graduate training to employed scientists and engineers through the medium of evening classes. Because of the heavy demand for evening work, a larger number of courses can be offered in the evening hours, and courses which could be offered in the daytime only at infrequent intervals can be offered more often. Day graduate students usually find it desirable and often necessary to take part of their course work in the evening classes in the same classes with employed engineers and scientists. The student who is employed during the daytime of course progresses more slowly, but the program has been arranged so that he may complete the requirements for the degree of master of science in one of the fields of science or engineering in a minimum time of three years, although the average time is somewhat longer, averaging between four and five years. In normal times, without interruption by service in the Armed Forces, the period for obtaining the master's degree is limited to five years.

Beginning in the fall of 1944, a co-operative arrangement was worked out with the Allis-Chalmers Manufacturing Company under which a similar program of graduate evening education was offered in the West-Allis plant of the company. The definite objective of this plan was to bring to the technical and scientific employees of the company graduate courses of the same caliber as those conducted by the Illinois Institute of Technology in Chicago. The same courses with the same course contents and, in so far as possible, the same instructors, are provided in West Allis as in Chicago. Experience with the plan proves it to be practical and effective. Enrollments have been consistently good, and the students have been serious and co-operative. Although the distance from the college campus to the plant is approximately 90 miles, the members of the staff who have made the weekly trip to West Allis for their classes have felt that the direct contact with industry and the discussion of current engineering problems provided a return to them in professional experience which was of considerable value and benefit. Most of the staff who have been teaching these courses have been enthusiastic about the plan, and have felt repaid for the extra trouble and effort.

The development of suitable research projects and theses in such a program involves certain difficulties, but with careful co-operation they can be overcome to a large extent. The selection of a suitable topic involves co-operation on the part of the institute staff and the engineers of the company in the division in which the student is employed, as well as the directors of the training program. The student is permitted to select a topic which is rather closely associated with his daily work, so that the co-operation of his supervisors can be ensured. The interest of the company in the project is helpful in making available the facilities of the company in laboratory and shop for the experimental work that may be required. In every case, of course, the student develops his thesis individually, and submits it for approval in the regular manner. Co-operation in direction of the project is provided by staff from the campus. If the director of the thesis on the staff of the institute is conducting classes currently in West Allis, frequent consultations with the student regarding the progress of his thesis are readily possible. If the thesis is developed under the supervision of another staff member, arrangements are made for periodic consultations between student and adviser, some of these conferences being held in West Allis and others in Chicago. Although the experience so far in developing theses is limited, there is every reason to believe that satisfactory results will be obtained. Experience thus far very definitely indicates that the off-campus courses are equal in caliber to those conducted on the campus, and that there should be no hesitation in the award of the master's degree on the same basis.

A graduate program of even longer standing has been conducted with the Caterpillar-Tractor Company in Peoria, Ill. In this program, no attempt has been made to develop programs leading to advanced degrees, but a comprehensive series of courses in advanced mathematics has been given over a period of years for the research engineers of the company. After a sequence of several courses in consecutive years, a second cycle of similar courses has been begun for the younger engineers who have been employed since the first cycle started. Here again, although the distance to the plant of the company is considerably greater, a regular member of the institute staff makes a weekly visit and gives the same courses as would be given on the campus. The results of the plan have been uniformly satisfactory. Other programs of a similar nature are under development.

To summarize these developments it may be said that with the full co-operation of industry and neighboring educational institutions, many opportunities for graduate technical education may be developed for engineers and scientists who are hungry for the training and have no other opportunities to obtain it. With proper care and control, there is every indication that taking the staff to the students instead of the students to the college campus is an adequate and satisfactory method of conducting graduate education which well may be augmented in the future by industry and education in co-operation.

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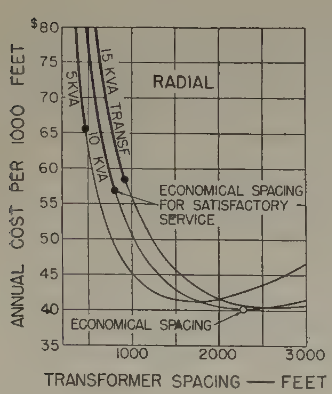
Transformer and Secondary Conductor Economics

BRYCE BRADY
MEMBER AIEE

MOST ELECTRICAL UTILITIES operate more mileage of 120–240-volt single-phase secondary distribution mains than any other transmission or distribution voltage. It is important that such secondary lines and the size and spacing of the associated distribution transformers be designed for over-all economy.

The advent of more and more appliances which cause voltage flicker in residential areas makes control of flicker a prime design consideration. Most of the flicker voltage drop resulting from the starting of small motors occurs in the distribution transformers and the secondary conductors.

The most accurate approach is to design the transformer-secondary system for total allowable flicker and steady voltage drops, and to let over-all economics determine how much voltage drop should occur in the transformer and how much in the secondary main. The result of using this approach on a system with reasonably high service quality is that thermal capability ceases to be the governing factor in selecting transformer sizes in many residential areas.



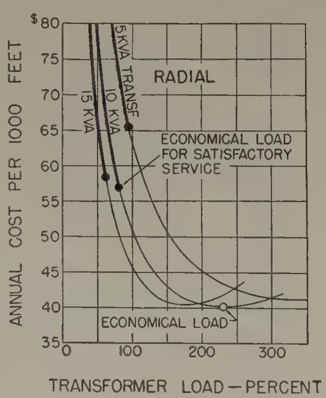


Figure 1 (left). Ten-kilovolt-ampere transformers spaced 813 feet provide the most economical satisfactory service in a residential area where the load density is 10 kva per 1,000 feet and the 120–240-volt secondary conductors are *Number 0* aluminum on the radial plan

Figure 2. Ten-kilovolt-ampere transformers loaded 81 per cent are more economical than smaller transformers loaded more heavily under the conditions stated in Figure 1

One of the objectives of this study is to determine the most economical loading of distribution transformers under various conditions. Another objective is to define the conditions under which secondary banking, as a means of controlling flicker, is economically justified. A third objective is to make an economic comparison of copper versus aluminum as secondary conductors under current price conditions.

The pertinent questions in periodic rearrangements to handle load growth are: What size transformers should be used? How far apart should they be spaced? How heavily should they be loaded? Figures 1 and 2 show the general form of the solution to this problem. This case is typical of nearly all of the practical situations encountered in distribution practice in that the most economical transformer size, spacing, and loading cannot be used because the quality of service would be unsatisfactory. The problem then is to choose the most economical combination which will meet the desired standard of service.

In this example, 10-kva transformers spaced 813 feet and loaded 81 per cent require the least annual cost. The radial secondary conductors are *Number 0* aluminum and the load density is ten kilovolt-amperes per 1,000 feet. Steady voltage drop in transformer plus secondary is limited to 6.6 volts and the flicker voltage drop resulting from the starting of 1/4-horsepower and 1/2-horsepower 115-volt motors is limited to four volts and eight volts respectively. These flickers should not occur more frequently than six or seven times an hour for the 1/4- and once an hour for the 1/2-horsepower motors for satisfactory service.

A similar analysis for banked secondary mains shows that 15-kva transformers spaced 1,667 feet and loaded 111 per cent represent optimum economy under the same conditions and permit a saving of $12 in annual cost per 1,000 feet. The cost is computed upon those items of investment, losses, maintenance, and operation, which are variables.

Similar analyses for a variety of conductor sizes and materials, at various load densities, lead to the following conclusions.

The loading of distribution transformers to thermal capability is not economical if it is necessary to make up for the voltage drop in ways more expensive than installing larger transformers. Under the premises of this study it is not economical to load distribution transformers as high as 100 per cent where the load density is 10 kva or less per 1,000 feet of radial secondary. On banked secondaries and on radial secondaries at higher load density, the most economical transformer loading ranges upward from 85 per cent.

The banking of secondary mains is definitely an economical method of limiting the flicker resulting from the starting of small motors in areas with load densities up to 18 to 40 kva per 1,000 feet, depending upon conductor size and material. Banking at higher load densities may be justified by other considerations.

Aluminum, with or without steel reinforcing, is attractive as a secondary conductor under current price conditions.

Digest of paper 49-10, "Distribution Transformer and Secondary Conductor Economics," recommended by the AIEE transmission and distribution committee and approved by the technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Universal Curves for D-C Reactors

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A D-C CONTROLLABLE REACTOR is an iron-cored inductor in which the a-c impedance can be varied over wide limits by magnetically saturating the iron with an auxiliary d-c winding. Because of its ruggedness, ease of control, and low losses, it has found continually wider application as a control device.

The purpose of this article is to present the results of an analysis of the steady-state characteristics of d-c controllable reactors, and to point out certain general conclusions. The results, which are presented in the form of universal curves, can be used in a straightforward quantitative manner, or they can be used qualitatively to enable one to determine, for example, the effect of using a magnetic material with different characteristics. Experiments indicate that the accuracy of calculation is generally within ten per cent, this being perhaps as high as can be expected in a nonlinear analysis.

The analysis is based on a representation of the magnetization curve of the core material by an expression of the form: $i=C_1\psi+C_n\psi^n$, where i is the instantaneous current, ψ is the instantaneous flux linkage, and C_1, C_n, and n are constants which depend upon the shape of the magnetization curve.

Two different groups of curves are presented, one drawn in terms of rms alternating current and the other in terms of average current. Different curves are given for each of the three values of n, 5, 9, and 15. This has been found to cover the range necessary for the usual magnetic materials. Other values of n can be used by interpolation. A sample set of curves is shown in Figure 1. The universal curves are plotted in terms of the following dimensionless groups:

I/I_b, where I is the rms alternating line current, and I_b is an rms base current selected arbitrarily, but at least as large as the greatest expected alternating current.

I_{av}/I_b, where I_{av} is the average alternating line current.

E/E_b, where E is the rms terminal voltage, and E_b is a base voltage corresponding to I_b on the saturation curve.

$a=\psi_0/\psi_b$, where ψ_0 is the d-c flux linkage of one a-c coil, and ψ_b is the maximum a-c flux linkage which would be caused by application of the base voltage, E_b.

$b=\dfrac{I_0N_{dc}}{I_bN_{ac}}$, where I_0 is the current in the d-c winding, N_{dc} is the number of turns on the d-c winding, and N_{ac} is the total number of a-c turns in series between the a-c terminals.

An important phenomenon in the operation of the d-c controlled reactor is the reduction in d-c flux that is caused by the alternating current acting on the nonlinear flux path. For this reason, the d-c flux is not related in a simple manner to the direct current.

The universal curves show an interesting comparison between the values of direct current required for core materials with different saturation characteristics. For example, in the curves for rms current, the fifth-power curve for $b=0.2$ corresponds very nearly with the 15th-power curve for $b=0.15$. The reduction in d-c excitation afforded by the much sharper-breaking curve is appreciable but perhaps not as great as one might expect. The reason is that the phenomenon of d-c flux reduction is stronger for the faster-breaking curves and tends to reduce their effectiveness to a certain extent.

A comparison on an average-current basis is shown in Figure 1, and here the difference between the various powers is strikingly small. In the lower-voltage region the sharper-breaking curves have an appreciable advantage, but at the higher voltages the reverse is actually true. Even the ideal magnetization characteristic with a vertical side and horizontal top does not affect the results greatly. The average-current characteristic curves have vertical sides at $I_{av}/I_b=2b$. The average-current curves are, of course, the important ones in circuits where the output is rectified, including those in which rectified feedback is employed.

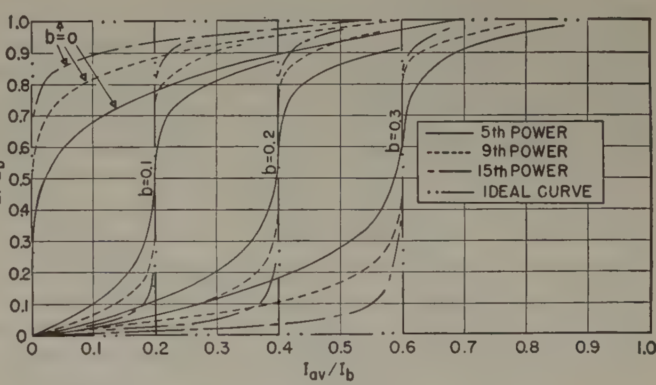

Figure 1. A comparison of the average-current curves

An important aspect of the analysis is the fact that the charts make it possible to calculate the d-c flux in the reactor without difficulty. This quantity is of major importance in the transient operation of the reactor. It cannot be measured satisfactorily under operating conditions because of the slowness of response of the device, and, as has been mentioned, it is not related to the direct current in a simple manner. Work has been started on an investigation of the transient response of d-c controlled reactors, using computed values of d-c flux as a basis for calculation. The preliminary results are encouraging.

Digest of paper 49-4, "Universal Curves for D-C Controllable Reactors," recommended by the AIEE transformer committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Surge Protection in a Watt-Hour Meter

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SINCE REDUCTION of maintenance was the primary objective for the development of a new watt-hour meter, detailed consideration was given during its design to the resistance-to-surge problem. By reducing the hazards of meter damage from surges, longer service periods without attention are possible. This provides savings which are particularly important to operating utilities under present conditions of increasing labor costs for maintenance and testing of meters.

The modern meter, as exemplified by this new design, must have the greatest practicable resistance to surge-current demagnetization of the permanent magnets and also to damage caused by voltage flashovers. Demagnetization of the braking magnets is particularly serious, since the resulting overregistration of the meter often poses difficult customer-relation problems. During the last 15 years, this hazard has been effectively reduced by using Alnico permanent magnets or by encasing the magnets in a conducting covering. Insulation damage to the meter components may or may not be equally serious,

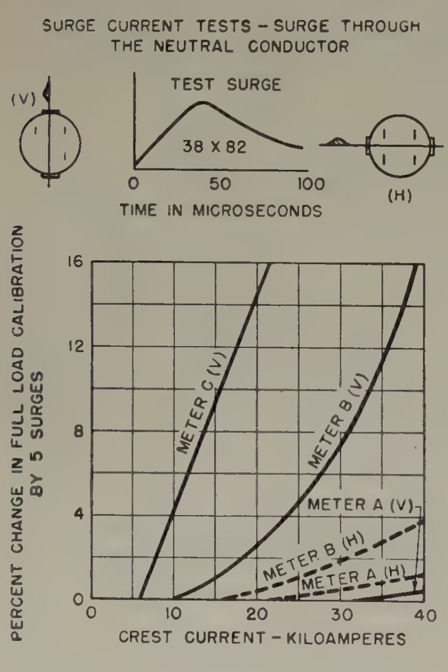

Figure 1. Results of lightning-type current-surge tests on watt-hour-meter calibration—detachable - type meter

Meter A—meter described in text
Meter B—meter of previous design with Alnico II magnet
Meter C—meter of previous design with chrome magnet

but, in any case, the cost of repair and replacement contributes directly to the utilities' expense of providing service.

The braking magnets in the new watt-hour meter utilize Alnico V, a high-coercivity magnetic alloy having properties especially suited to this application. The two C-shaped magnets are cast as inserts in the die-cast aluminum-alloy frame and are completely surrounded by the aluminum. Resistance to demagnetization by surge currents is attained by taking full advantage of the high coercive force of Alnico V and by the eddy-current shielding of the aluminum. The superiority of the new meter (meter *A*) for surge-current values up to 40,000 crest amperes is evidenced by comparison with chrome steel or Alnico II magnets used in previous designs (meters *B* and *C*), as shown by Figure 1.

A second application of a high-coercivity magnetic alloy has been made in this meter to achieve a superior method of supporting the meter rotor. The previous mechanical bearing, operating at high bearing pressures, has been eliminated by suspending the rotor by means of two small magnets, one fixed to the meter frame and the other to the top of the shaft. The magnetic alloy (Cunico) has an inherent high degree of coercivity which is supplemented by a jacket for the outer magnet of a conductive die-cast material which gives eddy-current shielding.

Considering insulations, the increase in sparkover levels obtainable by practical design improvements cannot be expected to eliminate the hazard of surge damage to the insulations of the meter coils or mountings. A lightning discharge between clouds and the earth produces a current flow which will induce a voltage across any impedances encountered. The magnitude of the surge current and the steepness of its wave front are often such that the voltage induced across the meter windings is many times the value at which the weakest point of insulation will spark over.

To reduce damage to the insulations to a minimum, however, the location of a sparkover point can be selected and predicted in the design, co-ordinating its impulse sparkover level with those of the other insulations. In the meter described, this has been accomplished by simple means. In the detachable S-type meter, brass pins riveted to the meter base provide definite air gaps to the line leads. The pins are riveted through the base to stainless-steel spring clips which contact the lip of the socket when the meter is installed, thus completing the grounding circuit. Similarly, on the bottom-connected A-type meter, a formed clip provides the sparkover relief gap from the line leads to ground.

Satisfactory co-ordination of the relief gaps and the insulation of the potential and current coils of the meter has been realized by improving the insulation strength of these meter components so that it is in excess of the flashover level of the gaps through the use of polyethylene and butyl rubber insulations. Variations in impulse levels between individual meters and for different test conditions are to be expected.

Digest of paper 49-20, "Surge Protection in a Modern Watt-Hour Meter," recommended by the AIEE instruments and measurements committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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New York-to-Schenectady Television Relay

F. M. DEERHAKE

Rebroadcasting of National Broadcasting Company originated television programs from New York, N. Y., by station WRGB in Schenectady, N. Y., has been carried on since 1940. Until 1947 this was done by receiving the New York signal near Schenectady and employing a short 160-megacycle link. Since that time a 4-link microwave relay has been in use on frequencies in the 2,000-megacycle region. This installation has shown definite advantages and is applicable for systems requiring a small number of links, with line-of-sight paths up to 60 miles.

A BOOMING television industry still is wrestling with the problem of programming stations, particularly those not located in the major metropolitan centers, without encountering prohibitive production costs. To *WRGB*, pioneer General Electric television station in Schenectady, N. Y., this is no new problem. Nine years ago when *WRGB* first was going on the air as *W2XB*, the possibility of rebroadcasting in Schenectady the programs of the National Broadcasting Company station in New York, N. Y., later to become *WNBT*, loomed up very attractively.

BACKGROUND

In spite of the fact that a true optical line of sight from New York City passed nearly 7,000 feet over the area in the Helderberg Mountains near Schenectady where the *WRGB* transmitter was located, it was found possible with suitable special arrangements to receive an adequate signal directly from the New York City transmitter. The special arrangements included use of a large rhombic antenna 400 feet long, supported by four 125-foot towers, and a low noise level preamplifier, as well as selection of a site relatively free of interference conditions and having a good exposure in the New York City direction. Under these conditions, programs were rebroadcast successfully for several years, using a 160-megacycle low-power transmitter to cover the short distance from the Helderberg receiving site to the *WRGB* transmitter.

This arrangement, while highly satisfactory in many respects, was subject to several obvious disadvantages as a permanent system, or as one to be recommended for general use. Picture quality and continuity of operation suffered to the extent resulting from passing the signal through two complete television broadcast transmitters. Some interference was inevitable at times because of the extremely low level of the desired signal at the receiver site. Program material was limited of course to precisely that actually broadcast by the particular station which could be received. But the thing which finally made the operation impractical was the shift of frequency of *WNBT* to the same channel as *WRGB*, which occurred in 1946. This created an intolerably high interference level at the receiver located only a mile from the *WRGB* transmitter.

An interim solution was achieved by locating a site some 40 miles from the *WRGB* transmitter which, by virtue of its location and conformation, received the New York signal with sufficient relative strength to permit tolerable reception even while *WRGB* was operating on the same frequency. A single link of 160-megacycle relay was still able to transmit the signal from this point to the *WRGB* transmitter. The degree of interference from *WRGB*, however, varied from a relatively low level to an unreasonably high level with atmospheric conditions and other variables, and the resultant picture quality subsequently was degraded very seriously at times.

THE MICROWAVE SYSTEM

The necessity for a higher quality relay system as a permanent solution already had been realized and work was well advanced on the extension of microwave developments, initiated during the war, to fill this need. Here at a frequency of about 2,000 megacycles was found a combination of advantages not possessed by either higher or lower frequencies. High enough to take advantage of antenna gains of the order of 1,000 to 1, making it possible to employ a relatively low power transmitter, yet low enough to avoid the extreme sensitivity to atmospheric conditions prevalent at wave lengths much shorter than ten centimeters, this frequency band gave promise of permitting satisfactory relaying operation with long relay links and consistent results. This promise has been amply justified by subsequent results.

Sites were selected as shown in Figure 1, providing four links from New York to Schenectady having lengths of 51, 53, 26, and 13.5 miles respectively. The intermediate relay sites selected were a point near the top of North Beacon Mountain, a point on the southwestern slope of Round Top Mountain, near Catskill, and the same site in the Helderberg Mountains used for the receiver in the original system, which received the New York signal directly. To facilitate programming, it was planned to relay into the Schenectady studio of *WRGB* from the Helderberg site and to return all program material, local or relayed, to the transmitter

Full text of conference paper originally presented at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948, and recommended for publication by the AIEE committee on communication.

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over another 2,000-megacycle studio–transmitter link. Selection of the relay sites was based on a combination of technical and economic reasons—a good line of sight between successive stations, best possible accessibility, availability of electric power, cost of land, and various other factors.

Identical towers were erected on the three intermediate sites. Because of the experimental nature of the system, the tower, shown in Figure 2, was more pretentious than would be required for its immediate use. It provided an enclosed room 28 feet square and 125 feet above the ground with three plywood panels in each of the north and south walls to permit a maximum of three antennas to be directed either north or south from inside the tower. Doors and a hoisting boom in one side of the elevated room provided for the hoisting of heavy equipment. A stairway also was provided, as was a small building inside the base of the tower, for emergency power supply, power termination facilities, and, in addition, for use as emergency living quarters.

MICROWAVE EQUIPMENT FOR THE PRESENT SYSTEM

The radio equipment installed in each of the three towers was identical, consisting of a 6-foot parabolic reflector directed southward for the receiving antenna; the receiver, installed in a temperature-controlled cabinet, and its power supply; the transmitter, also installed in a temperature-controlled cabinet, and its power supply; and a second identical reflector, directed northward, for the transmitting antenna. The original installation included two complete sets of this equipment at each tower, to provide for both video and audio transmission, but the second set of equipment later was removed to another video installation, wire lines being retained for transmission of the audio signal. To complete the system, a set of transmitting equipment was installed atop the General Electric Building in New York, N. Y., and a set of receiving equipment at the *WRGB* studio site in Schenectady.

The block diagram, Figure 3, is illustrative of the transmitting and receiving installations at all sites. Physically, power supplies are located at some distance from the corresponding receivers and transmitters, particularly at the terminal installations. However, it is necessary to locate the transmitter near its antenna to insure proper loading for the klystron transmitter oscillator. Distance between receiving antenna and receiver is limited only by allowable attenuation in the interconnecting cable. At the Schenectady terminal 120 feet of *RG 19/U* cable are in satisfactory use with the afore-mentioned relatively short 13.5-mile radio transmission path.

The microwave transmitter stresses simplicity of radio-frequency circuit which consists exclusively of the *SRL-7* klystron oscillator tube with self-contained cavity, the connecting transmission line with matching section, and the antenna radiator. The klystron oscillator is frequency-modulated to a maximum total swing of ten megacycles by a video modulator capable of 100 to 125 volts output from a low impedance output final stage. D-c reinsertion at this point maintains a fixed frequency for synchronizing peak level and insures maintenance of limits of frequency swing regardless of picture content of the modulating signal. The transmitter may be tuned to any point within the band of 1,825 to 2,100 megacycles and provides five to ten watts of output power. Over the 10-megacycle normal operating swing, amplitude modulation is quite small, being of the order of 10 to 20 per cent with typical tubes. Linearity of modulation is adequate for single-link operation without special precautions. However, for the multilink operation encountered in this system, it was believed desirable to use a slug-type matching section as shown in Figure 3. This allows fine adjustment of the load impedance into which the klystron operates, and thereby permits some compensation of the small curvature of modulation characteristic which otherwise would be cumulative in several successive links.

Frequency control of the transmitter is achieved by operating in a temperature-controlled cabinet, and by maintaining careful electronic regulation of the various voltages applied to the klystron. By these means, the random frequency variation after a 15-minute warmup period may be held readily to a fraction of a megacycle. For the type of transmission being used, with a 10-megacycle frequency swing, maintenance of absolute frequency closer than half a megacycle has been proved to be of little practical value.

The receiving equipment employs the same type of

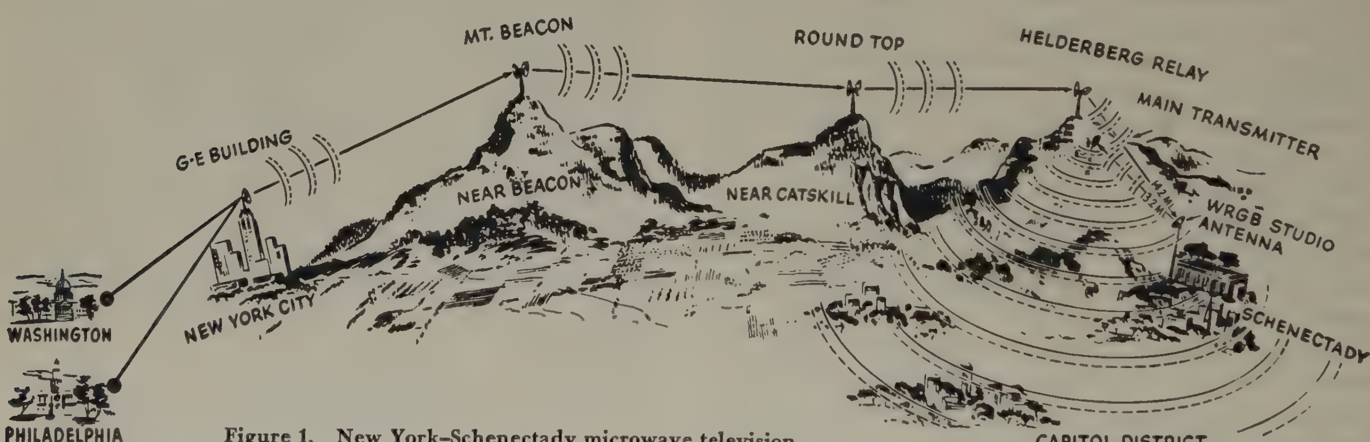

Figure 1. New York–Schenectady microwave television relay

antenna as the transmitter. The *SRL-7* klystron is used here also as a local oscillator, but at reduced filament and resonator voltages which permit extremely long life. A *1N21B* crystal mixer feeds a signal into an intermediate-frequency amplifier consisting of three stagger-tuned triplets using *6AK5* tubes. A double limiter, conventional wide band discriminator, and video output complete the receiver. The intermediate-frequency amplifier in the original receivers had a center frequency of 100 megacycles. At the Mt. Beacon station this subsequently has been reduced to 90 megacycles to avoid interference from a frequency modulation broadcast transmitter which has been installed at the same location since relay operation began. As a more general solution, present design has an intermediate-frequency center frequency of 125 megacycles to avoid possibility of interference from any high-power television or frequency modulation broadcast transmitters. Intermediate-frequency band width and discriminator width of approximately 15 megacyclesa re employed in all cases to provide for some frequency tolerance and to permit adequate passage of high-frequency side bands. As in the transmitter, temperature control of the receiver cabinet and electronic regulation of klystron voltages serve to hold the local oscillator frequency constant.

A double limiter is employed ahead of the discriminator. Screen current of the first limiter is metered to provide a continuous indication of signal level. At the remote stations this screen current is passed through a sensitive relay for remote control purposes. These receivers run continuously, and are connected through control circuits so as to turn on the transmitter at each location when the screen current in that receiver exceeds a predetermined minimum value. Thus turning on the New York City transmitter produces a high level of limiter screen current in the Mt. Beacon receiver which turns on the Mt. Beacon transmitter and so on until the entire circuit is operative. When signal is removed, the entire transmitter chain turns itself off in reverse fashion.

OPERATING RESULTS

Including an initial period of experimental operation, the relay system now has been programming *WRGB* for a large percentage of its operating time for well over a year. During the first six months of 1948, 421 hours of program were carried, climaxed by a maximum of 105 hours in June with approximately one per cent lost time for equipment difficulties principally due to lightning as noted in the following. Chief among the problems to be overcome to attain this operating record was that of high humidity and temperature variation at the remote towers. Moisture condensation resulted in some component failures and caused blowing of fuses during early stages of operation. This was cured by placing equipment at these points in cabinets which are maintained somewhat above outside ambient temperature. Replacing fuses by slower operating, self-reclosing circuit breakers, which are not subject to tripping by surges, has been instrumental in the prevention of loss of operation for this cause.

No failure of the circuit definitely attributable to signal fading caused by atmospheric conditions has occurred, although some variation in signal strength has been noted during heavy storms. However, a more violent atmospheric phenomenon, lightning, caused a temporary outage during the summer of 1948. This occurred at the Mt. Beacon station, which is erected on rock foundation near the top of

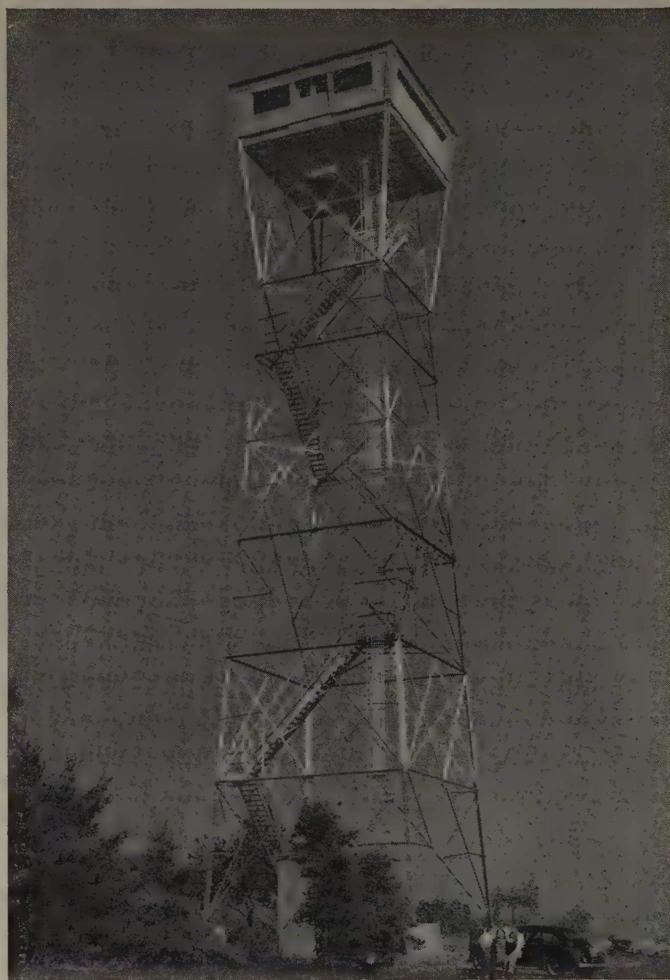

Figure 2. Television tower

the mountain. Grounding of the tower by rods sunk ten feet into the earth and rock proved inadequate, and a more adequate ground consisting of a cable sunk into a deep well now has been provided.

Since the only special and costly tubes required by the system are the *SRL-7* klystrons, tube life figures on these are of importance. To date, average operating life of transmitter klystrons has been about 3,000 hours. Operation of the same type tube under reduced voltage conditions as a receiver local oscillator has resulted in life in excess of 10,000 hours.

As might be expected, no interference problems in the 2,000-megacycle range have been encountered because of the general scarcity of equipment operating in that range. As mentioned in the foregoing, intermediate-frequency interference in the 100-megacycle region was encountered from a 1-kw broadcast transmitter with antenna located

about 100 feet from one of the receivers. Transmitters in other sites at distances of half a mile or more have caused no trouble.

NEW DESIGN FEATURES

Experience with the equipment in the New York–Schenectady relay has led to a number of refinements in present design. Arrangement of transmitter components in the temperature-controlled cabinet to permit ready access to all controls for tuning, adjusting gain, or applying test signal without seriously affecting temperature conditions has been stressed. Power supplies with wider safety factors have been designed to permit satisfactory operation with ±5 per cent variation of line voltage, while maintaining excellent voltage regulation, negligible ripple, and operation of components at conservative ratings at all times. A built-in saw-tooth test signal has been provided for rapid checking of linearity and magnitude of modulation. Portable packaging has been designed for the transmitter and its power supplies for those conditions where it is desirable to transmit from various different points of origin.

In the receiver, automatic gain control is provided together with improved limiting to permit operation over wider limits of signal level. An input signal of 200 microvolts is adequate to provide good limiting. Automatic frequency control of the receiver local oscillator has been added to permit operation of the receiver without temperature cabinet for all ordinary uses. As mentioned in the foregoing, the intermediate frequency has been shifted to a range where interference never should be encountered under normal operation.

FUTURE USES OF THE EQUIPMENT

In common with many other types of radio transmission, difficulty has arisen in finding enough frequency spectrum to satisfy everyone who wishes to use this type of equipment. After several tentative proposals, a Federal Communications Commission frequency allocation has been made of seven channels covering the range from 1,990 megacycles to 2,110 megacycles for "television pickup, television studio-transmitter links, and interim television relay." Under this arrangement, television stations may obtain license for operation in either of the first two categories for an indefinite period, and for a privately owned multilink relay, in the third category, for such time as it is operable without interference to pickup or studio-transmitter link operations of other stations.

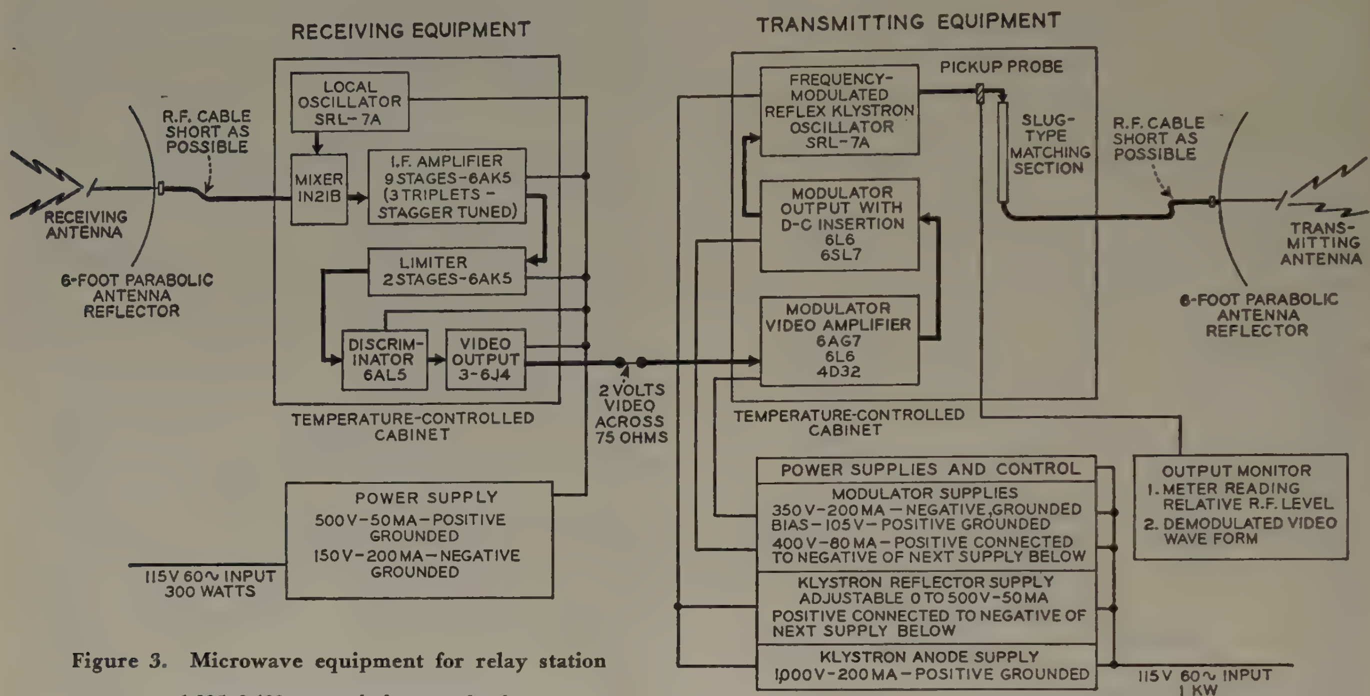

Figure 3. Microwave equipment for relay station

1,825–2,100-megacycle frequency band

Thus, while this results in channeling much of the permanent network operation into those facilities operating as common carriers on the frequencies assigned for common carrier applications, the field for privately owned short relay systems is not closed. Except in the largest metropolitan centers, a careful arrangement of frequency assignments and transmission paths in the 2,000-megacycle band can minimize the interference problem to the point where the limited number of channels available can accommodate much of the required service for both studio-transmitter and intercity relaying. The 2,000-megacycle equipment then offers attractive advantages in consistency of propagation and in cost where a few relatively long relay links can cover the required distance. A system which demodulates to video at each relay point is very useful for interconnecting a group of stations where programs may originate and be fed into the system at any of the several points. And finally, initial and maintenance costs can be lower than for common carrier systems which must be capable of operation over long distances, with 50 or more links in tandem, and hence must meet extremely high standards for quality of reproduction with each individual piece of equipment incorporated in the system.

Stray Electric Currents in Coal Mines

L. H. HARRISON
MEMBER AIEE

THE HAZARDS represented by stray electric currents in coal mines and earth strata have been a major problem since electric shot-firing methods were introduced some years ago. The accident records of the mining industry are replete with instances of premature explosions and shot-firing accidents of various kinds for which the only logical explanation is stray electric currents in the earth.

The sources of these stray electric currents are, in all probability, numerous and varied. Two principal sources of such currents in the earth are lightning discharges to the surface of the earth, and a combination of power circuits and electric equipment used for operation of the mine.

The first source is, of course, one about which little or nothing can be done. The second source is largely preventable, although complete elimination of such currents, even from these sources, is virtually impossible. Certain precautionary measures can be taken, but the effectiveness of such measures can be increased greatly by well-planned electric installations and proper maintenance.

When a discharge of lightning occurs, the visible disturbance in the atmosphere is only part of the complete stroke mechanism. At the time of discharge, an electric disturbance takes place within the originating cloud formation; likewise, a similar disturbance also is set up in the earth when discharges to the earth's surface occur. Electric currents of enormous intensity flow in the earth under discharge conditions. The earth offers resistance to the flow of current, and voltage gradients are built up in the earth's strata. Such voltage is enough to detonate explosive charges at a considerable distance from the point of entry into the earth.

Currents caused by lightning, either direct strokes or from induced charges, are carried into the underground workings through mine tracks, pipe lines, or electric feeder circuits and are dissipated in the earth. Thus differences of potential are created which have been known to cause the detonation of explosive charges several thousand feet from the mouth of a mine.

Short-circuiting of the detonator lead wires or shot-firing lines previous to the actual firing undoubtedly has prevented many premature detonations. This method, however, is not entirely effective in preventing such accidents. It is possible that heavy currents in the earth caused by lightning discharges could start a current to flow in the closed blasting circuit by the process of induction. Tests made at the Bureau of Mines' experimental mine at Bruceton, Pa., indicated that a voltage could be induced in an insulated wire buried in a shallow trench.

Abundant evidence has been accumulated to prove that lightning has caused the detonation of explosive charges in underground and open pit mines. Such instances have occurred under circumstances in which the secondary cause would appear to be electric currents flowing in the earth strata owing to lightning discharges from cloud formations to the earth's surface.

The other main source of stray currents in coal mines, unlike lightning, presents a constant hazard: stray currents from mine feeder systems and haulage tracks.

Perhaps the most prolific source of stray currents in coal mines is the haulage track. The grounded track is the return power conductor for the locomotives and other equipment receiving power from the trolley circuit. It inherently presents a low resistance contact to earth, and thus any difference of potential due to voltage drop in the track circuit also appears in the mine strata. Differences of potential can be measured between various points of contact in the mine floor, ribs, or roof; such differences give rise to the flow of stray currents in the mine strata.

Water spray lines and frame-grounding conductors connecting the bonded mine track with the frames of mining machines and coal-loading equipment provide a low-resistance path for stray currents into the face of a room or wall.

Another source of stray currents is leakage from an accidentally grounded conductor of a mine feeder system. Grounded power conductors frequently have caused mine fires owing to leakage of current heating and igniting the coal; this is conclusive evidence of the flow of current in the mine strata.

On 3-phase Y-connected grounded neutral power systems, enough current may flow in the earth under fault conditions to cause premature detonation of explosive charges. This may be true even where a grounding conductor is installed with the feeder system, unless provision is made for limiting the fault current by means of resistors or reactors in the grounding circuit.

Electrolytic action upon the metallic sheath or armor of power and telephone cables is another harmful result of stray electric currents. Such deleterious action, though not ordinarily hazardous to human life, results in damage to expensive cables and may result in costly outages.

The notoriously careless manner in which electric installations are made in and around coal mines is an important factor in producing stray currents. The benefits to be derived by the reduction of such currents to a minimum are not always tangible. The Bureau of Mines for many years has recognized the dangers represented by haphazard and inadvertent methods of installing and maintaining electric equipment in coal mines, and has endeavored to bring about an improvement in the general quality of mine electric installations by disseminating knowledge and by inspection and assistance. The Federal Mine Safety Code has been helpful in bringing about such improvement. Considerable progress has been made but much remains to be done.

Digest of paper **48-318**, "Causes and Effect of Stray Electric Currents in Coal Mines," recommended by the AIEE mining and metal industry committee and approved by the AIEE technical program committee for presentation at the AIEE Southern District meeting, Birmingham, Ala., November 3–5, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Development of a Small D-C Motor

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THIS SUBJECT is a matter of prime importance to a manufacturer of standard National Electrical Manufacturers' Association machines. Because of the necessity for meeting a series of ratings in a given frame size, the method of approach to the problem differs from that used to design a machine for only one rating.

Reference to the NEMA standards ("Motor and Generator Standards," NEMA Publication 38–49, May 1938, National Electrical Manufacturers' Association, New York, N.Y.) will provide certain limiting dimensions and a list of ratings for a particular frame size. Design efforts should be directed first towards the most difficult ratings in the series. There are many variables to be determined in a d-c design for a single rating. If a basic design can be adapted to other ratings with a minimum of redesign then the basic design is successful. The optimum design would have one set of mechanical parts, such as armature core, commutator, pole pieces, and frame with various armature windings, to meet ratings at other speeds and voltages. The optimum can be approached if the proper order in determining variables is followed.

The outside diameter of the frame can be determined from NEMA dimensions. Approximately 50 per cent of this dimension should be used for the armature diameter.

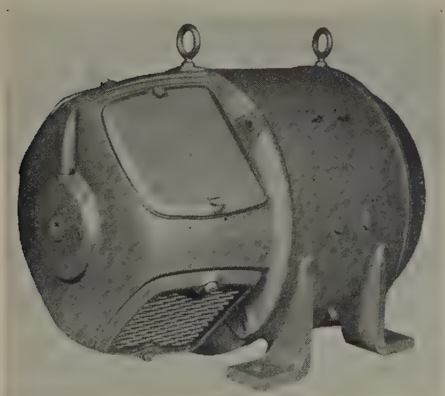

Figure 1. Complete NEMA frame 284 d-c motor

NEMA ratings range from 1–10 horsepower, 500–3,500 rpm, and 10.5–15 pound-feet of torque, and are standardized for 115 and 230 volts

The length of the armature core may be determined by empirical formulas or by actual calculation. The latter must be made after a winding is selected and limits of flux density established which can be met by varying the core length.

For a small 4-pole wave-wound machine, either an even or an odd number of armature slots can be used. An odd number of slots permits a fractional-pitch armature winding. This may be used to an advantage in short-pitching the armature winding for the purpose of reducing demagnetizing armature reaction and also reducing the short-circuited electromotive force in the conductors undergoing commutation. Performance is improved by a large number of slots but the correct number must be determined by analysis of the results of armature design calculations.

The selection of a good armature winding is important as it is the most desirable variable to have for meeting ratings at different speeds and voltages. If the designs were to be made for the 1,750-rpm 230-volt motor, then the number of wires per slot should be an integer which has practical multiples for the ratings at other speeds and voltages. Consider 24 wires per slot in a wave winding for the foregoing rating. For 115 volts, 12 wires per slot can be used. To meet 1,150 rpm, 36 and 18 wires per slot may be used for 230- and 115-volt ratings respectively. If instead of 24, the original number had been 18 wires per slot, the 115-volt rating would require 9 wires per slot. Since 9 is an impossible number of wires per slot to wind, 8 or 12 must be used and the flux changed inversely proportional to the variation from 9.

The number of segments in the commutator is a function of the number of slots used in the armature and the number of sections per coil. Three or four times the number of slots gives a quantity of segments that limits bar-to-bar voltage to a reasonable value for good commutation. The maximum number of bars is limited primarily by cost and mechanical considerations.

Detailed armature designs must be made in accordance with commonly used methods. If all combinations of the best approximations for number of slots, slot detail, wire size, and wires per slot are used for calculations, then the best combination can be determined by comparison of losses as well as core length required.

The four main poles commonly used in the small motors are built up of punched laminations. The face should cover 60 to 65 per cent of the pole arc and the shank should be dimensioned to give some saturation for best performance. The calculation of a saturation curve and design of a shunt field to give the required excitation are matters of common procedure to the d-c machine designer. The commutating field is generally designed for half as many interpoles as main poles.

The design constants should be used to calculate over-all performance and heating. A check of reactance voltage and ratio of armature back ampere-turns to exciting ampere-turns will give indications of commutating ability and stability. A complete testing program must be carried out on sample motors built in accordance with the designs. If the key ratings meet the predicted performance, it is not necessary to build samples of all ratings before releasing the designs for pilot or production manufacture.

Digest of paper 49-15, "Development of a Small Integral-Horsepower D-C Motor," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Designs for Fluctuating Loads

P. S. DICKEY   P. R. LOUGHIN

Considerable progress has been made in the development of boiler units and control equipment to meet the special requirements of fluctuating loads. This article discusses various designs so as to show what load fluctuations are possible and what limitations are encountered in planning for this type of load.

UNTIL recent years the practice among operators of large electric generating systems was to carry relatively constant loads at efficient operating points on newer generators and to carry load swings on numerous older units. As a result of recent growth, a larger proportion of total generating capacity is carried on the newer units as the older units are not always capable of handling system load swings.

Since these modern generating units will be subjected to fluctuating loads, it is well to explore the problems involved. This article discusses design of boilers, fuel-burning equipment, and automatic control in an effort to show what load fluctuations are possible and what limitations are encountered in designs for this type of load.

All modern steam boilers and fuel-burning equipment and auxiliaries are capable of handling load fluctuations of reasonable range and rapidity. Attention should be called, however, to a number of types of steam generators which on account of special operating conditions must be capable of extremely fast fluctuation in load, and in some cases must be suitable for operation over an extremely wide range.

Central stations which supply power to a utility system in which a large proportion of the power generating capacity utilizes water power and is thus subjected to occasional instantaneous stoppage on account of transmission line failures usually require this type of steam generating unit. In recent years, there has been a great deal of interest on the West Coast in steam generating plants capable of very rapid pickup in load. At the moment, this interest has lessened; first, because all available power generating equipment in this area is being worked to the maximum capacity at all times and, second, because steam power generating equipment is becoming a larger proportion of total system capacity and thus is unlikely to be subjected to extremely fast and large load changes.

Likewise, marine boilers of all kinds must be capable of fast changes in load over a wide range because of the need for maneuvering the ship. A load range of as much as 20 to 1 and continuous maneuvering between the minimum and maximum loads are standard operating conditions for this type of boiler. Locomotive boilers are subject to considerable load fluctuation, and the boilers have been built with very large water storage which provides accumulator action to effectively compensate for the lack of responsive firing equipment.

Figure 1 shows a design of central station boiler unit recently installed in a West Coast generating station. This design is a modification of a standard radiant boiler to adapt it for extremely rapid load pickup. It is equipped with a 72-inch-diameter steam drum to provide increased water storage capacity and to provide space to accommodate the rise in water level that occurs during a rapid load pickup. The unit normally is fired with oil, but also is equipped to burn natural gas. The burner design and fuel-supply and control systems are unusual in that they are designed to be capable of an operating range of 20 to 1 with all burners in service burning oil fuel. The superheater incorporates the

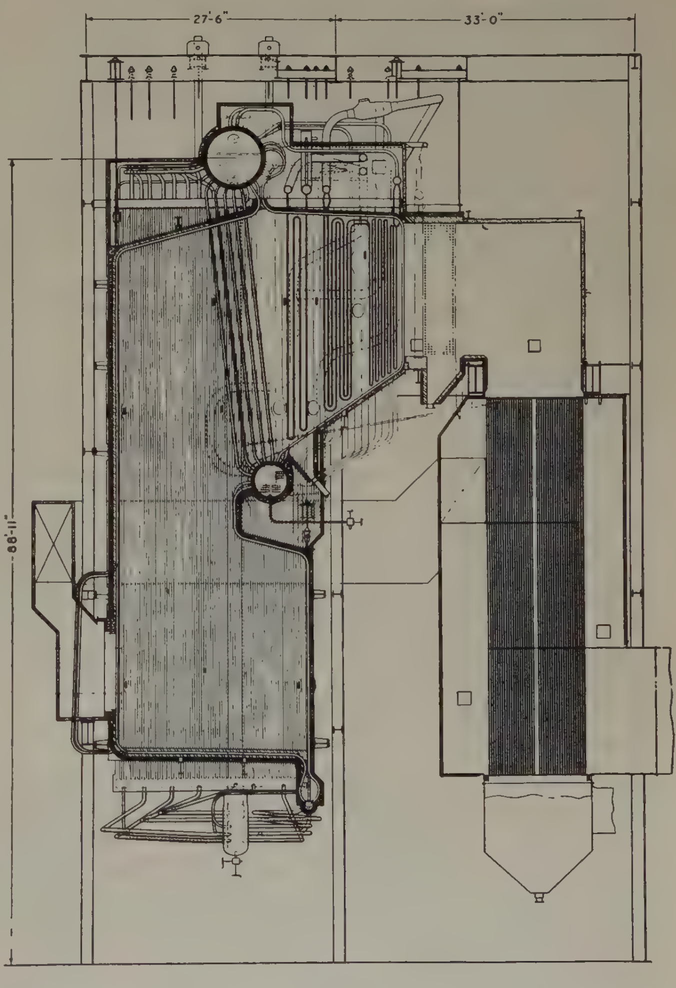

Figure 1. Central station boiler designed for rapid load pickup

Essential substance of paper 49-97, "Design of Boilers and Control for Fluctuating Loads," recommended by the AIEE system engineering committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *TRANSACTIONS*.

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most recent improvement in surface arrangement to cope with the oil fuel slagging problem characteristic of units fired with presently available grades of fuel oil. The unit has special provisions for washing the superheater, economizer, and air heater surfaces during outages for cleaning.

FACTORS WHICH GOVERN PICKUP TIME

If we examine Figure 2 which shows a typical set of conditions encountered during load pickup on a steam generating unit, we find there are two phases, the first being the time when heat supplied from combustion is less than heat delivered in the steam output and steam pressure is falling as in phase *A*. Phase *B* represents the time when heat supplied is in excess of that taken out in steam. Steam pressure is being returned to normal and temperature conditions within the boiler are being changed to provide a balance between supply and demand and a restoration of normal steam conditions. Various design conditions affect the characteristic load pickup curve.

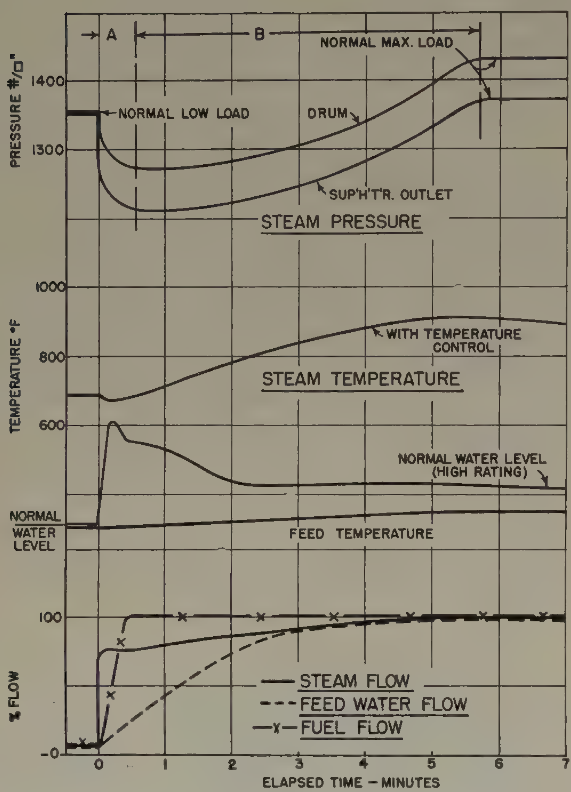


Figure 2. Boiler conditions during full load pickup

Accumulator Action. Since most of the water in the boiler is at saturation temperature corresponding to the pressure, and since the drum and tubes in the steaming zone of the boiler are likewise at a corresponding or slightly higher temperature as indicated in Figure 3, heat may be withdrawn from this boiler water and the metal parts upon a reduction in pressure and corresponding reduction in temperature. The following example of accumulator action of the boiler shown in Figure 1 illustrates the extent of heat storage and accumulator action available for making steam during the period when the fuel or the heat supply is deficient.

Temperature of saturated pressure parts at start of phase *A* (Figure 3)	584 degrees Fahrenheit
Temperature of saturated pressure parts at end of phase *A* (Figure 3)	577 degrees Fahrenheit
Difference	7 degrees Fahrenheit

Weight of metal in saturated pressure parts = 482,000 pounds

Heat available from storage in metal parts $= 482{,}000 \times 7 \times 0.1 =$ 337,000 Btu

Heat content of saturated water in boiler at start of phase *A* (Figure 3)	594.7 Btu per pound
Heat content of saturated water in boiler at end of phase *A* (Figure 3)	580.1 Btu per pound
Difference	14.6 Btu per pound

Weight of water in boiler = 78,000 pounds

Heat available from storage in water in boiler $= 78{,}000 \times 14.6 =$ 1,140,000 Btu

Total heat available from storage $= 337{,}000 + 1{,}140{,}000 = 1{,}477{,}000$ Btu

Heat required to flash one pound of steam = 594.4 Btu

$$\text{Steam generated from storage} = \frac{1{,}477{,}000}{594.4} = 2{,}480 \text{ pounds}$$

2,480 pounds of steam will supply the steam output demand following the load pick-up (Figure 2) for about 22 seconds.

$$\frac{(2{,}480 \times 3{,}600)}{400{,}000} = 22$$

Temperature Rise in Metal Parts. In order to achieve a higher rate of steam generation, a temperature gradient corresponding to the increased flow of heat through the metal tubes is required, as illustrated by Figure 3. In addition, if turbine throttle pressure is to be maintained constant at low and high loads, the boiler drum pressure must be increased to provide for increased pressure drop through the superheater and steam piping at high rates of steam flow. The increased temperature gradient and the increased metal and water temperatures caused by the rise in saturation temperature are indicated. The amount of heat which must be added before the increased steam generation under normal operating conditions can be achieved based on the boiler shown in Figure 1 is illustrated by the excess firing rate shown by the fuel flow curve on Figure 2. This "overfiring" continues for about 5.5 minutes after the load increase occurs.

Since in modern high-pressure boilers only about one-third of the heat liberated in the furnace is absorbed in the steam generation section of the boiler, the actual heat required to raise the metal and water temperatures as outlined in the foregoing, is as follows:

Maximum oil firing rate following load increase	= 36,200 pounds per hour
Normal oil firing rate at 400,000 pounds per hour steam flow	= 27,100 pounds per hour
Excess firing rate during recovery period	= 9,100 pounds per hour

Calculated duration of recovery period = 5.5 minutes

$$\text{Overfiring during recovery} = \frac{9{,}100}{27{,}100} \times 100 = 33 \text{ per cent}$$

If an attempt were made to recover normal conditions in one-third of the 5.5 minutes (or 1.8 minutes) without

increased steam pressure drop, approximately double the normal firing rate would be required to heat the water and metal parts.

Time Required to Accelerate Steam Release. While steam can be generated in nearly all portions of the generating section of the boiler upon reduction in steam pressure and conversion of water at saturated temperature to steam, this steam must be released to be useful. Even at the maximum circulation rate, an appreciable length of time, depending upon the over-all height of the boiler, is required for steam bubbles to reach the drum. Since these steam bubbles are entrained below the water level, some water in the steaming tubes must be displaced by steam bubbles occupying a larger volume, resulting in a substantial increase in level in the drum as indicated in Figure 2. Since nothing can be done to prevent this surge resulting from a rapid increase in steam generation, the drum must be made large enough to absorb the surge without permitting a level high enough to result in carryover. Careful consideration of drum design and drum baffles, therefore, is required for quick pickup boilers. Figure 4 shows a design of cyclone separators that is particularly well suited for this extreme condition. All of the steam and the circulating water are collected from the riser tubes by the manifold baffle and then passed through the cyclone separators before being discharged into the main part of the drum.

Figure 4 illustrates how the steam and water are discharged from the separators. Tests have shown that a

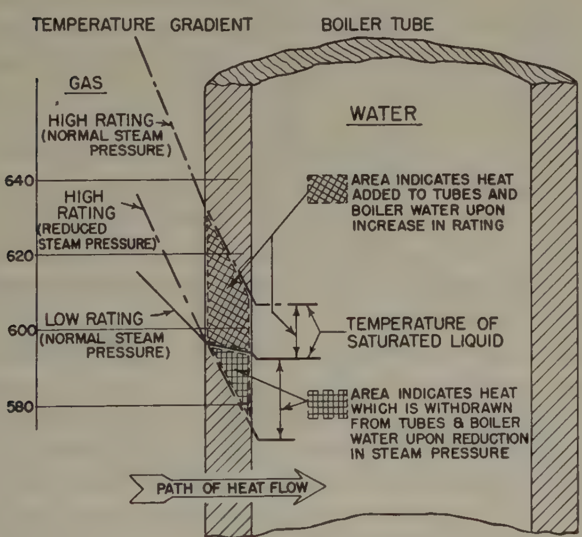
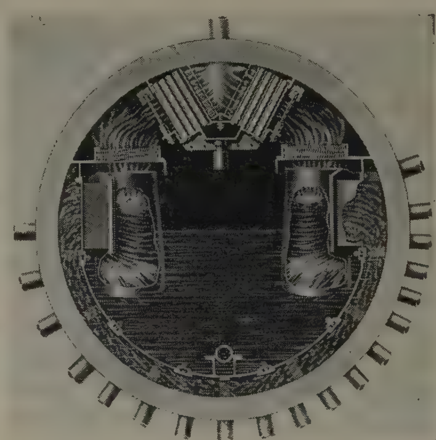


Figure 3. Average temperature of boiler tubes

satisfactory quality of steam is delivered from the drum as long as the water level in the drum is not above the top of the cyclones. For the unit shown in Figure 1, this will permit a variation in water level of approximately 20 inches. This should be ample for the surge in water level that will occur on this unit equipped with a 72-inch-diameter steam drum. A type of feed water control must be selected which will permit a large fluctuation in water level without seriously upsetting the smooth regulation of feed water to the boiler.

Time Required to Accelerate Heat Release. While the time required to accelerate the loading on a steam turbine is limited only by the time required to open the steam valves (since the unit already is operating at full speed), the time required to accelerate the combustion and heat release to the boiler is limited by other factors. In order to achieve the maximum heat release, the fuel supply and combustion air supply must be co-ordinated carefully so that best

Figure 4. Cyclone separator



combustion conditions are maintained during the accelerating period. A large excess of air during acceleration may result in less than optimum furnace temperature and lower heat absorption by the steaming section of the boiler. A deficiency of air will result in a larger loss on account of unburned fuel.

In view of the critical nature of the fuel-air relation during accelerating periods, it is felt that with large furnaces from five to ten seconds must be allowed to accelerate the fuel and air supply and still maintain suitable combustion conditions during the process. Where variable speed fan drives are used, the accelerating time usually is limited by the time required to accelerate the speed of the fan, as discussed later in the article.

Practical Limit of Overfiring. It already has been pointed out that "overfiring" is required to limit the steam pressure fall and to restore steam pressure to normal after the load increase. Serious consideration must be given to the practical limit of overfiring as this not only increases the initial cost and operating cost of fans and fuel-burning equipment, but also dictates design of the superheater, economizer, and air-heater heating surfaces of the boiler, and determines the extent and cost of steam temperature limiting devices necessary to keep steam temperature within safe limits. It already has been pointed out that approximately two-thirds of the heat released in the furnace goes to the superheater, economizer, and air-heater sections. If a substantial amount of overfiring occurs during the load pickup, this overfiring will tend to increase steam temperature above normal, increase economizer outlet temperatures above normal, and raise air temperatures

above normal. Fortunately, there is a considerable mass of metal in all of these sections of the boiler so that steam temperature, economizer outlet temperature, and air-heater outlet temperature will not rise quickly. This is obvious from the typical load pickup curve of Figure 2. However, unless a proper balance is established between the amount of overfiring, the time required to restore conditions to normal, and the mass of metal in these convection sections of the boiler, excessive temperatures may result.

The superheater is particularly critical with respect to the amount of overfiring, and some means of temperature limiting control usually is required to maintain steam temperature within safe limits on quick pickup-type boilers.

Figure 5 shows a typical design of surface heat exchanger type of attemperator. This type of design was used on the unit illustrated in Figure 1 with the tube bundles installed in the lower drum of the boiler bank. The steam from the primary superheater bank passes through a 2-way control valve to the attemperator tube bundles or through the by-pass and then to the inlet header of the secondary superheater. Operation on many units with the attemperators of this type have shown that this type of steam temperature control when properly designed will give good control even on rapid load changes. Figure 6 shows another type of attemperator that is being used widely on many modern units. This is an interstage spray-type attemperator. It is employed only where the feed water used as the spray water is low-solids condensate. Operation has shown that its response to rapidly changing load condition is excellent.

Permissible Steam Pressure Drop. By designing the steam turbine to carry the maximum load under reduced pressure and temperature conditions, the boiler and combustion problem is simplified since full advantage may be taken of the accumulator action of boiler water and metal parts, and an economical amount of overfiring will be sufficient. For plants requiring quick pickup over a wide range in load, consideration should be given to the relative cost of adding capacity to the turbine to permit full load under

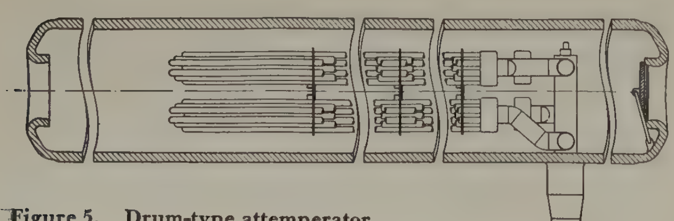


Figure 5. Drum-type attemperator

reduced pressure and temperature conditions versus added capacity in the boilers, steam temperature control, and draft and fuel-burning systems, to permit suitable overfiring.

Reduced Frequency. From Figure 7 it is fairly obvious that any modern steam generating plant having a fuel-burning system of adequate range, suitable auxiliaries, and automatic control can pick up load instantaneously to a value which is between 70 and 80 per cent of the maximum capacity of the boilers and turbines. During this instantaneous pickup, steam pressure will fall according to a pattern similar to that shown in Figure 2 and the turbine will carry the load under reduced pressure and temperature conditions. With a very limited amount of overfiring and, therefore, no more than normal overcapacity on the boiler, draft, and fuel-burning equipment, steam conditions can be restored in the period of from five to ten minutes so that the turbine then can be carrying its full rated load within that time. From the standpoint of economical design and most efficient operation under normal load conditions, such a plant designed for quick pickup of a portion of the maximum load and with allowance of additional time to reach the full rated load seems to have considerable merit. Some system frequency change may result during the period while conditions are being restored to normal.

FUEL-BURNING EQUIPMENT

In general, any of the commercial fuels may be utilized in furnaces for boilers designed for rapidly fluctuating loads.

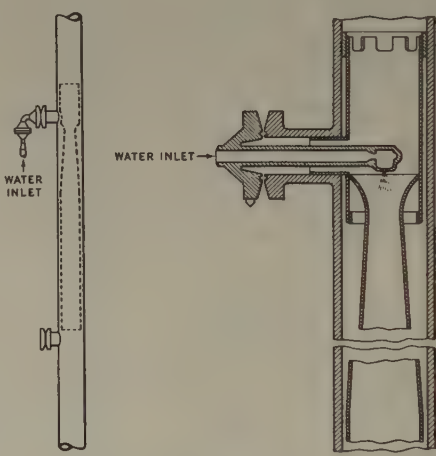


Figure 6. Spray-type attemperator

Generally, the type of fuel and fuel-burning equipment affects the extent of the operating range more than the speed of response.

Gas Firing. Gas firing is suitable for boiler furnaces subject to fluctuating loads. A wide range of operation and very rapid changes in firing rate are possible without undue complication of the fuel-burning equipment. A range of about ten to one without combustion difficulties and complication in burning equipment should be available. However, since gas is so easy to burn, it is one of the most dangerous fuels; in order to avoid explosions, it is essential that an extremely accurate and reliable control system be applied if the unit is to be subjected to rapidly fluctuating loads over a wide range. Extremely close proportioning of the fuel and air relation is essential to safe and efficient operation with this fuel.

Oil Firing. Oil burners are available in the steam atomizing or return flow type, which permit operation over a range of at least 12 to 1 without combustion difficulties. While the hazards involved may not be quite so serious as with gas firing, extremely close proportioning

of the fuel and air supply is essential to safe and efficient operation of oil-burning combustion equipment. For all practical purposes, the oil-burning combustion system is equally as responsive as gas-fired equipment.

Pulverized Coal. Properly designed pulverized coal burning equipment is very responsive to load changes and may be used readily on boilers designed for rapid load fluctuations, except that the range of operation and thus the range of load fluctuation is limited. Pulverized coal-burners of conventional design will not permit operation through a range of more than three to one and specially designed pulverized coal burning systems rarely exceed four to one without removing burners from service. Since it already has been pointed out that for quick pickup in load, the heat release should be accelerated in about ten seconds or less, it is obvious that there is not sufficient time to start pulverizers, change burner combinations, and so on, so that the range of operation of a pulverized coal-fired boiler for rapidly fluctuating loads is limited unless special and extensive provisions are made.

Stokers. Boilers fired by underfeed or spreader stokers are reasonably satisfactory for rapidly fluctuating loads but over a limited range of operation. Some types may be operated over a reasonable range, but difficulties undoubtedly will result if instantaneous and unexpected load changes of great magnitude are encountered regularly.

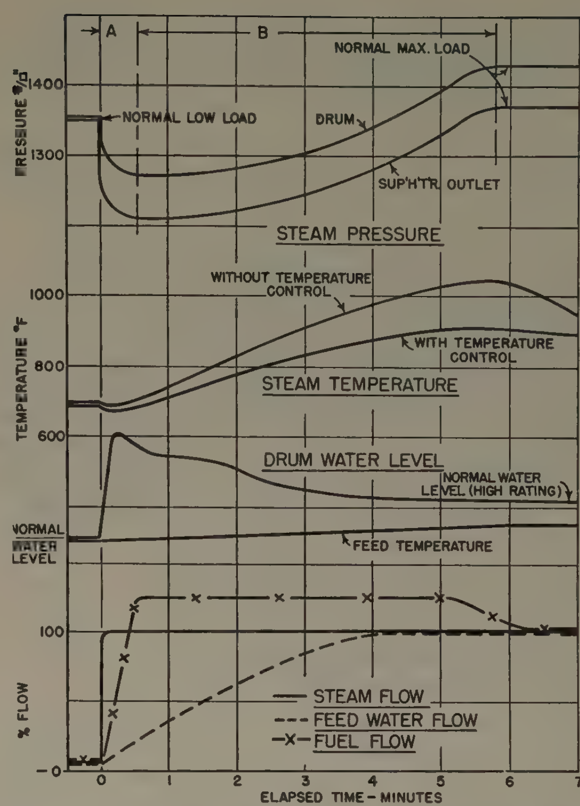


Figure 7. Boiler conditions during 75 per cent limited load pickup

DRAFT EQUIPMENT

Constant speed or variable speed drives for induced- and forced-draft fans may be used on boilers subjected to rapidly fluctuating loads. However, since the rate of load change is determined entirely by the rate of change of combustion, which is limited in turn by the rate of change in combustion air supply, careful consideration must be given to the accelerating characteristics of variable speed fans. In general, higher speed fans with smaller wheels and lower inertia are better adapted to quick changes, but consideration must be given to the wear and over-all life on this type of fan.

Constant speed motors with damper or vane control of air supply provide most rapid variations, but are not economical if the plant is to operate for extended periods at reduced loads.

A suitable compromise seems to be adjustment of fan speed over a limited range with damper control to supplement the fan speed control. From the acceleration curves shown in Figure 8 for various types of fan drives, it will be noted that the acceleration and deceleration rate from 50 to 100 per cent speed is much faster than corresponding rate of speed below 50 per cent, so that it would appear that, where variable speed is desired for purposes of economy and life, the speed range should not be extended beyond two to one, because of reduced response.

By utilizing a speed range of not more than two to one, a substantial saving in fan horsepower is achieved and substantial reduction in fan wear is realized. In view of the rapid acceleration and deceleration characteristics above 50 per cent, no serious loss in maneuverability is encountered.

Damper control for regulation below 50 per cent of capacity provides adequate speed of operation and further provides more precise regulation necessary to maintain good fuel-air relationships over any extended range.

ARRANGEMENT OF AUTOMATIC CONTROLS

Design Characteristics. In general, the automatic control equipment used on a boiler designed for rapidly fluctuating loads is similar to that used in the usual installation. The functions of the automatic boiler control for a quick pickup plant are identical with those of the average plant. The primary functions are

1. To supply heat to the boiler in accordance with the demand for steam.
2. To proportion accurately the fuel and combustion air supply.
3. To supply the correct amount of feed water.
4. To maintain the proper steam temperature.
5. To protect against failures of boiler and auxiliaries.

and the secondary functions are

1. To maintain proper furnace draft conditions.
2. To divide the load evenly among all boilers under control.

If the boiler is subjected to wide and rapidly fluctuating loads, however, the demands on the control are much more severe than in the average installation. It has been pointed out that all power units driving dampers, valves, and other regulating devices must be capable of full stroke operation in from five to ten seconds with perfect stability. The control must be designed to maintain the fuel and air relationship with a high degree of accuracy in order

to achieve the maximum heat release in the furnace and in order to safeguard against explosions or other hazardous types of operation. Some additional special features are desirable in the automatic boiler control system.

Combustion Control. A study of Figure 2 reveals that a single-element control of combustion from steam pressure

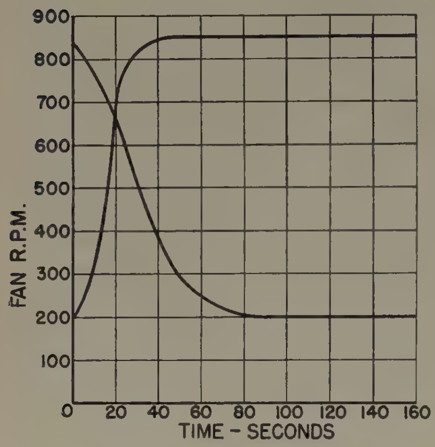


Figure 8. Typical acceleration and deceleration curve for variable-speed fans

(which is the usual method) is not adequate for a boiler subject to wide and rapidly fluctuating loads. It already has been shown that under these conditions, the steam pressure will fall and return to normal according to a definite pattern determined largely by the boiler design and by the extra capacity of the fuel-burning equipment. If the combustion control were actuated from steam pressure alone, the range of regulation from steam pressure must be narrow in order to obtain a rapid pickup of the fuel and air supply and as a result the control would go out of range and lose control for a considerable portion of the pickup cycle.

To overcome this difficulty, the 2-element control is used. In this system, the supply of fuel, forced draft, and induced draft are actuated in parallel primarily from a measure of the demand as indicated by the steam flow. This primary control immediately establishes fuel, forced-draft, and induced-draft settings at approximately the correct amount in accordance with the load on the boiler. The steam pressure control then makes only whatever readjustments are necessary to maintain the correct steam pressure conditions.

In order to insure safe operation, it is essential that the fuel and air supply be proportioned correctly. To accomplish this, the parallel control with readjustment is used. Any changes in load cause parallel and proportional changes in the fuel, forced-draft, and induced-draft settings simultaneously. Since this parallel control cannot regulate these settings precisely, a metering-type fuel flow-air flow proportioning controller readjusts the supply of air to maintain a correct fuel-air relation.

Likewise, a metering-type furnace-draft controller readjusts the relation between forced draft and induced draft to maintain proper furnace conditions.

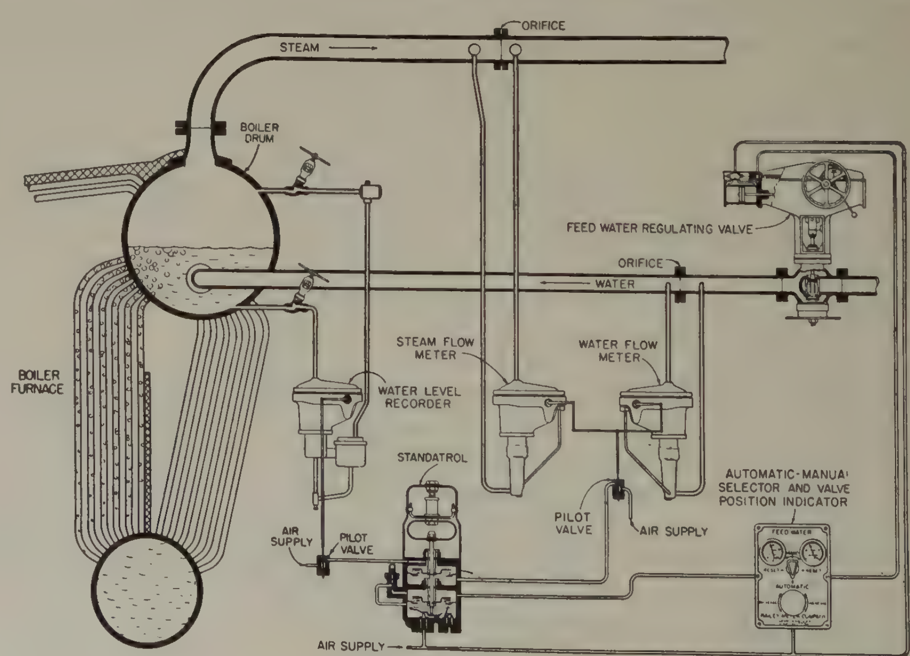
Some variations of this general system are used for different plant operating conditions. However, the fundamental principle of utilizing the multiple-element control from steam flow and steam pressure to control all factors in parallel upon changes in load, and the metering-type fuel-air proportioning controller and furnace draft controller to readjust and thus maintain precise relationships among the various factors is a sound arrangement for boilers subject to rapidly fluctuating loads.

Feed Water Control. It has been pointed out that there is an appreciable time period between the beginning of the increase in steam output and firing rate, and the complete release of steam bubbles generated beneath the water line. In view of this increased quantity of steam below the water line, a surge in water level must result from an increase in load.

Since the drum water level is subject to sizable amounts of surge and shrinkage, a feed water regulator actuated only by an indication of drum level will be in error much of the time, and will have difficulty in proportioning the feed water to the steam output and thereby maintaining proper feed water regulation.

The 3-element system of feed water control which proportions the flow of feed water to the flow of steam primarily, with readjustment from drum level, is the logical solution for this problem. It has been used extensively on high-capacity high-pressure boilers for many years. Smooth regulation of feed flow is obtained and the fluctuation of water level in the drum is kept to the minimum

Figure 9. Three-element feed water control



for any particular design of boiler. This system is illustrated in Figure 9.

The characteristic of water level variation and feed water flow control during load pickup is illustrated on Figures 2 and 7. With the 3-element system of control it is easily possible to adjust the control to maintain a high water level at high rates and a lower water level at low rates so as to increase effectively the drum capacity to accommodate water level surge or shrinkage upon load changes. Likewise, by proper adjustment of the relative range of regulation of the level control and of the flow proportioning control, practically any pattern of feed water flow can be maintained during load swings.

Steam Temperature Control. From Figures 2 and 7 and from the previous discussion, it is noted that, on account of the large amount of heat capacity in the metal of the superheater section of the boiler, there is a very considerable lag in the response of steam temperature to firing rate. While this capacity is beneficial in reducing the rate of steam temperature change, it introduces a considerable lag in the response of the steam temperature to changes in furnace conditions. Upon changes in load there is a very substantial time delay before the steam temperature levels out to a value corresponding to the new load on the boiler.

In view of this fact, the steam temperature control system normally recommended for boilers subjected to fluctuating loads is a 2-element system involving an indication of boiler load and of superheater outlet temperature. The flow of combustion air rather than the flow of steam is used normally as the measure of boiler load; first, because of the ease of tying this indication into the steam temperature control and, second, because if an excess of combustion air exists a higher heat absorption in the superheater will result, and this index applies the proper adjustment to the steam temperature control.

Where split superheaters are used with attemperators between primary and secondary sections of the superheaters, it has been found advantageous in some cases to control primarily from an indication of boiler load and steam temperature at the outlet of the attemperator (entering secondary superheater). A temperature measurement at this point gives a rapid indication of the steam temperature leaving the attemperator, and is independent of the capacity storage and resulting slow response in the primary superheater. By maintaining a predetermined temperature condition entering the secondary superheater, a minimum of control from the temperature indication at the outlet of the secondary superheater is required. Such a 3-element system of steam temperature control has been found very satisfactory in a number of installations where temperatures of 950 degrees Fahrenheit and above are maintained.

Performance. Figure 10 shows performance of a destroyer-type boiler with operating conditions simulating rapid maneuvering over the full power range. It will be noted that each of the numerous load changes follows a pickup cycle similar to those previously described. It is interesting to note that a suitable boiler can be subjected to numerous and frequent changes of large magnitude without any instability or other unsatisfactory conditions resulting.

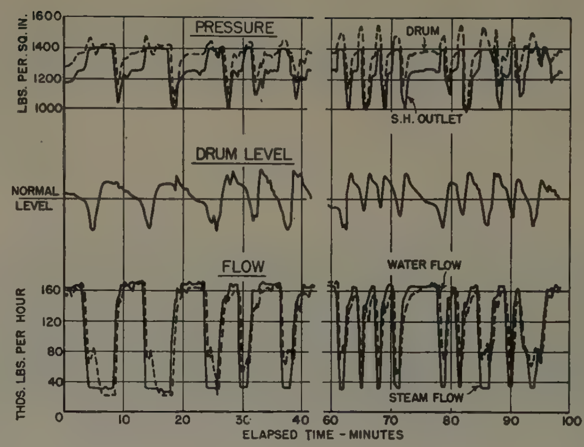


Figure 10. Load swing test, destroyer-type boiler

It is apparent from consideration of the many problems involved that the interrelationship of controls and boiler design is such that it is of utmost importance to have complete co-operation and co-ordination between the boiler designer and control designer to obtain a combination that will produce the optimum result from the viewpoint of practical and safe operation. In order to obtain the most economic over-all combination for units required to meet extreme and rapid fluctuations, the turbine designer must participate in the combined effort. By so doing, the best balance can be obtained between turbine and generator output at reduced steam pressures versus unit storage capacity or overfiring capacity.

Radar "Blips" Are Bugs

Mysterious radar reflections which have baffled the world's electronic experts both during and since World War II have been explained by A. B. Crawford of the Bell Telephone Laboratories in the April issue of the *Proceedings* of the Institute of Radio Engineers. The cause: flying insects. Nicknamed "angels," the heretofore unexplained reflections, or "blips," have shown up on many radar scopes as sharp echoes of short duration, observable most frequently below heights of 3,000 feet.

In tests sponsored jointly by the Bell and Naval Electronics Laboratories, all attempts to synthesize "angels" by artificially varying atmospheric conditions failed, but visual observations of insects coincided strikingly with the inexplicable radar "blips."

In one test, conducted at night, the insects were illuminated by a strong searchlight beam, while observers, stationed at different levels on a 200-foot tower, counted them. Simultaneously, radar operators counted "angels." In one 15-minute period, 15 "angels" coincided with the sighting of an insect.

An Improved Dual-Circuit D-C Generator

D. B. HOOVER
MEMBER AIEE

A DUAL-CIRCUIT generator as described in this article is a 4-pole d-c generator with one commutator and two load circuits. Each load circuit is independent of the other circuit, with respect to load, voltage, and polarity, although they are not electrically isolated from each other. Figure 1 shows how the load circuits are connected to the armature. This type of generator is not new, but until recently it was built with two commutating poles. One commutating pole had one winding excited by the current of one circuit, and the other commutating pole had one winding excited by the current of the other circuit. Commutation was the limiting factor in the older design, and required the generator to be underrated as compared to a standard d-c generator.

The improved dual-circuit generator has four commutating poles with two windings on each pole. One winding on each pole is excited by the current of one circuit, while

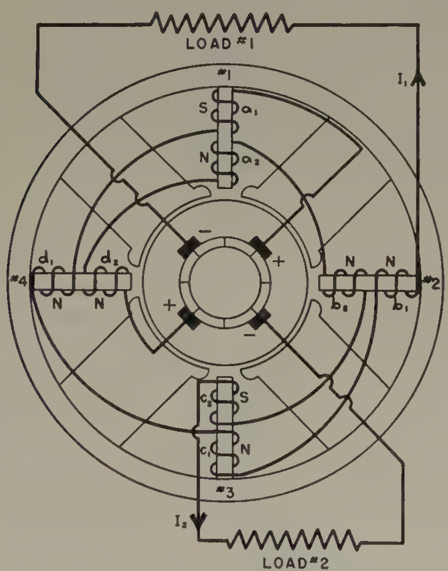


Figure 1. Load circuits and commutating field connections of the dual-circuit generator

the other winding on each pole is excited by the current of the other circuit. The new-design dual-circuit generator does not require underrating and commutates satisfactorily for any condition of loading.

Dual-circuit generators may be used to supply two motors in applications that require one generator per motor. In such cases, the dual-circuit generator saves space as mechanical parts are required for only one generator. For example, two bearings are required for the dual-circuit application, whereas at least another bearing would be required if two half-size generators were used. The dual-circuit generator is larger than one of two individual half-size generators, but it does not require twice the floor space of an individual half-size generator, as considerable space is saved on bearings and winding extensions.

The armature of a dual-circuit generator has a single lap-wound winding, similar to a standard d-c generator, except that no equalizer connections are used. The current distribution in the armature winding of a dual-circuit generator when both circuits are loaded equally is the same as for a standard d-c generator.

In Figure 1 it is seen that, each commutating pole has two coils, one coil in each circuit. The number of turns of each coil must be determined by consideration of the armature magnetomotive force and by the reactance voltage of the coils being commutated for all possible load conditions.

The voltage that appears at the brushes of any one circuit is dependent on the excitation of the two main poles of that circuit. Equal excitation of normal polarity on all four poles will give equal circuit voltages of normal polarity. If the main poles of only one circuit are excited, no voltage appears across the brushes of the other circuit. Likewise, reversing the polarity of the main poles of one circuit reverses the polarity of the brushes of that circuit.

Tests on a new-design 68/68-kw 250-volt 1,200-rpm dual-circuit generator were completed a year ago, and since that time several more of these generators have been built. The tests showed that the commutation was satisfactory with either circuit loaded from zero load to overload. Tests with reversed polarity on one circuit indicated some saturation of the frame and commutating poles, and this must be taken into consideration in the design. Temperature tests showed that normal rating could be secured from this generator with excellent commutation.

Previously, a generator of the same rating was built using the older, 2-commutating-pole design and a somewhat longer armature core. This older design did not commutate well with unbalanced loads and required special attention on the test floor to achieve successful commutation, even though this generator was underrated for its size.

The improved dual-circuit generator can be built on the same frame size as a standard d-c generator of the same capacity, temperature rise, and overload rating. Commutation of this improved generator is as good as a comparable d-c generator both at full load and overload. The new-design dual-circuit generators are now in use on shovel applications and are performing satisfactorily. It is possible that the use of this type of d-c generator will increase to include many applications when its characteristics and performance become more widely known.

Digest of paper 49-17, "An Improved Dual-Circuit D-C Generator," recommended by the AIEE rotating machinery committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Magnetic Fields Surrounding Recording Wires

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THERE are certain applications for magnetic recording that require the storage of information in the form of coded pulses in magnetic media such as wire or tape. To conserve space, it is necessary to record the greatest number of pulses in each linear inch of the medium that is possible without the pulses losing distinctness or objectionably blending with the preceding or succeeding pulses. Studies of the magnetizing current, pulse width, and frequency as related to this blending have been made, using wire as the recording medium. During the studies it became evident that useful information could be obtained if the size of the pulses as recorded on the wire could be directly determined. A wire retaining magnetically recorded pulses is similar to a succession of short cylindrical magnets laid in a line and connected end to end by a permeable medium. Therefore, if the magnetic field surrounding these minute magnets could be mapped and the pattern photographed, the distance between the magnetic poles could be determined easily. As is well known from elementary physics, iron filings when scattered about a magnet are not only attracted to the magnet but also arrange themselves in definite lines that apparently begin and end at the so-called poles of the magnet. These lines of iron filings are said to "map" the magnetic field. In a similar way, the magnetic field of extremely small magnets can be mapped if the iron particles are sufficiently small and proper techniques are used in producing the patterns.

Investigations were made on the magnetic recording of pulses in electron digital computers. Since the dimensions of the cylindrical magnets involved are very small (0.005 inch in diameter, 0.010 inch long), special techniques are necessary. The wire in the form of a continuous loop is magnetized by current pulses in a ring-type recording head which is essentially an electromagnet with a very short air gap (approximately 0.001 inch long). The wire moves in a shallow groove along the head and is tangent at the air gap. The amplitude, width, and repetition rate of the pulses are adjustable and can be determined easily. In order to minimize the effect of wire speed on the length of the magnets, a wire speed of eight to 12 inches per second is used so that during a single magnetizing pulse the wire moves only 0.0001 to 0.0002 inch. After the wire is magnetized, the recording head is disconnected, and the recorded pulses are picked up by another head and fed into a cathode-ray oscillograph through a preamplifier. If these play-back pulses are satisfactory, the driving motor is stopped and a sample of the wire is taken. In order to obtain the wire sample, the wire is stretched across a clean glass plate with sufficient tension to hold the wire tightly to the glass surface. A few drops of melted flake shellac are used to cement the wire to the glass plate at two points approximately three inches apart; this affords an ample number of pulses for study; then it is placed on the stage of a standard Bausch and Lomb contour measuring projector.

Digest of paper 48-237, "External Magnetic Field Patterns Surrounding Minute Portions of Recording Wires," recommended by the AIEE communication and basic sciences committees and approved by the AIEE technical program committee for presentation at the AIEE Middle Eastern District meeting, October 5–7, 1948, Washington, D. C. Not scheduled for publication in AIEE *TRANSACTIONS*.

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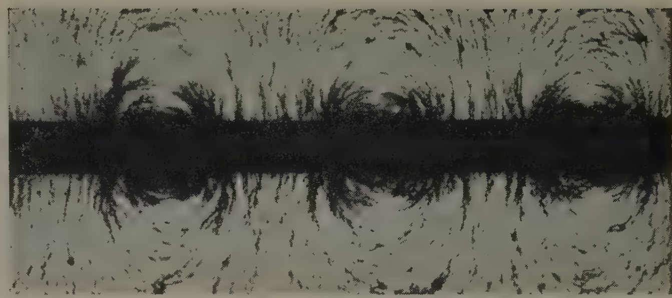

Figure 1. Pattern obtained with three pulses of alternate polarity

The use of fine magnetic powders to delineate external magnetic fields and to detect local inhomogeneities in magnetic materials is well known. The application of this method to "mapping" the external field of the tiny magnets in our problem requires fine magnetic particles. Moreover, to obtain clean patterns with the weak magnetic forces involved, requires the particles to move freely as directed by the forces, and to have a slow settling time. These requirements can be met if a suspension of magnetic particles is used, provided the proper density of the vehicles is used for the size, shape, and mass of the particles. After considerable experimentation, it was found that carbonyl iron particles (having an average diameter of approximately 0.0001 inch) suspended in a light oil are suitable for bringing out the desired fineness of detail in the pattern, when using a magnification of 150 diameters.

Therefore, a drop of iron particle suspension is placed on the wire. The iron particles settle at a rate suitable to give a definite and distinct pattern of the external field of the wire. The particles in the strongest field (near the wire) are attracted and adhere to the magnetized portion of the wire and build up a pattern in a few minutes that extends out a distance approximately equal to one-half to the full diameter of the wire. The portion of the pattern that is produced on the glass plate takes longer for the settling to be completed since the magnetic forces acting there are much smaller. Usually a satisfactory pattern will be produced in approximately 30 minutes. During the entire settling process and subsequent photographing, precautions are taken to prevent any jarring or movement of the glass plate.

Figure 1 shows three magnets produced in a wire with pulses of 40 milliamperes peak current, 70 microseconds duration, and a pulse repetition rate of 60 pulses per inch. The shape of the current pulses was approximately rectangular.

Coaxial-Cable Line-Tuning Equipment

HOWARD J. SUTTON
ASSOCIATE AIEE

THE ADVANTAGE of using low-loss cable in conjunction with power-line carrier equipment has been recognized for some years. The use of this cable has made it possible to locate the carrier transmitter-receiver in the most convenient place rather than out near the capacitor which couples the carrier signal to the power line. Coaxial-cable connections have resulted in much more flexible carrier installations than was possible before this type of cable was used.

To understand the behavior of coaxial cable we must consider this type of cable as a network rather than a simple 2-wire conductor. The outside shield surrounding the inside conductor introduces both series inductance and shunt capacitance. Coaxial cable, as in the case of a simple network, has a surge or characteristic impedance which approximates a constant regardless of the length of the cable or the frequency being conducted. The characteristic impedance of the cable most used for carrier frequencies falls between 60 and 70 ohms.

A network or coaxial cable must be terminated in an impedance equivalent to its characteristic impedance to prevent standing or reflected waves, the presence which increases distortion and losses. If, however, the length of the cable used is short, 200 feet or less for frequencies below 150 kc, the presence of reflected or standing waves will not present a serious problem.

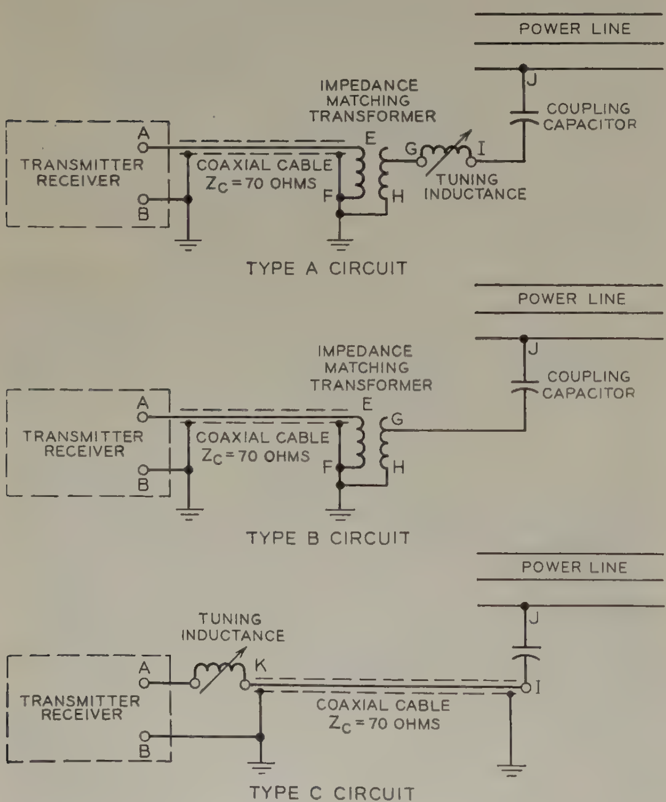

Figure 1. Type-A, Type-B, and Type-C circuits are shown

Not only is the coaxial cable a network, but the power line over which the carrier is transmitted behaves as a network. In the case of the power line, the characteristic impedance or 33-kv and 66-kv lines measured varied from 300 to 600 ohms. The balance of the discussion will be confined to three different types of coaxial-transmission line-tuning circuits called type *A*, type *B*, and type *C*.

Type-A Circuit. The conventional type-*A* circuit, as shown in Figure 1, may be used with coaxial cable without limitation at carrier frequencies. In this circuit, the tuning inductance is adjusted so that its reactance is equal numerically to the capacitive reactance of the coupling capacitor. The surge or characteristic impedance of the power line is assumed to be 500 ohms.

A transformer *EFGH* is used for matching the line impedance to that of the cable. Winding *EF* is connected to the coaxial cable. The connection to the *GH* winding is varied so that the 500-ohm load appears as a 70-ohm load across the *EF* winding. The coaxial cable then is matched to its characteristic impedance and maximum efficiency or low attenuation is obtained.

The type-*A* circuit presents very nearly a resistance-type load to the carrier transmitter throughout the frequency range. It is the most efficient of the types to be discussed. The chief disadvantage of the type-*A* circuit over the other circuits is the cost of the equipment and additional cost of installation.

Type-B Circuit. This coaxial transmission circuit is the same as the type-*A* circuit (see Figure 1), except the line-tuning coil (*GI*) is omitted. The connection to winding *GH* is varied so that the impedance of the capacitor in series with the line impedance of the power line appears as a 70-ohm load across the *EF* winding.

From tests performed, it has been found that the type-*B* circuit can be used in a frequency range of 75 to 150 kc if the coupling capacitor is 0.00275 microfarad or greater and the length of the coaxial cable does not exceed 400 feet. If used in the foregoing range the losses of this circuit will be only slightly greater than the type-*A* circuit. The main advantage of the type-*B* circuit is that the only outdoor line-tuning equipment required is the impedance-matching transformer which can be mounted in the base of the coupling capacitor.

Type-C Circuit. Another circuit which might be used to eliminate the outdoor line-tuning equipment is the type-*C* circuit. In this circuit, the line-tuning coil is located indoors in the transmitter-receiver carrier cabinet. For a coaxial-cable length of 200 feet or less with a frequency of 100 kc or less, the behavior of this cable approximates the characteristic of a simple conductor closely enough to permit the use of the type-*C* circuit. In this limited range, the losses of the type-*C* circuit compare favorably with the type-*A* circuit.

In a great many applications, the usual outdoor line-tuning cabinet equipment can be eliminated by using either type *B* or type *C* or a combination of both without affecting the performance of the carrier transmitter-receiver.

Digest of paper 49-6, "Line Tuning Equipment Used With Coaxial Cable for Carrier Current Installations on Power Lines," recommended by the AIEE carrier current committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Rubber Insulators for Pole Lines

H. H. WHEELER W. F. MARKLEY

Glass insulators on pole lines in some areas are subject to much mischievous breakage by children and hunters who utilize them in target practice, sometimes to the extent that almost weekly replacements are necessary. To solve the problem, a vulcanized rubber insulator has been developed which has proved in test to be both durable and efficient.

LIKE SO MANY modern developments, the use of rubber insulators on pole lines is the unexpected outcome of research originally started in a somewhat different direction. Observations over many years had shown that substantial annual sums were spent in replacing glass insulators mischievously broken, and that such breakage was confined largely to specific and well-recognized locations which seemed especially to lure children or hunters to destructive activities; sometimes one or two poles in a particular area required insulator replacements almost weekly. Figure 1 shows an example of such mischievous breakage.

In the initial consideration of this problem, some thought was given to the idea of improving the glass itself; that is, making the insulator from tempered or shatterproof glass in order to improve its resistance to breakage, but it was found that such a design was impracticable. Thought also was given to the idea of surrounding the glass petticoat with an outer metallic skirt, and although this attachment gave a surprising degree of protection, it was not entirely satisfactory.

The next device that was tried was a moulded rubber shroud over a small glass insulator of the pony type. This too developed a satisfactory degree of protection against blows, but was rather costly because of the volume of rubber required. It became obvious at this point that the real solution of the problem was to make the insulator itself of rubber. Although it was believed at the time that a suitable rubber compound could be developed possessing adequate physical characteristics and insulating properties, there was some question as to whether any such compound would have a useful life outdoors of more than three or four years.

Mechanically, the rubber composition had to be strong enough to carry the load of a telephone or telegraph wire and yet be sufficiently resilient so as not to crack when struck; it was also important that the insulator maintain its resilience and not crack or check for a reasonable period when subjected to the heat and ultraviolet rays of the sun.

Considering electrical qualities, surface leakage obviously accounted for so large a fraction of the current losses that high volumetric resistivity of the material was not a necessary requirement. In a dry atmosphere, the surface leakage over any insulator is negligible, but in the presence of moisture two major conditions affect leakage. The first is the specific heat conductance of the material, or in popular expression, whether it feels cold or warm to the touch. On good heat conductors, water precipitates out of the atmosphere more freely and at smaller temperature differences than on poor heat conductors. The other condition has to do with the interfacial tension between water and the insulator surface, or more popularly, whether or not water "wets" the surface. A small quantity of water on a surface with which it has a high interfacial tension, tends to draw itself up into a series of discrete globules, not touching each other and with dry surfaces between. Such a condition is conducive to low electrical leakage over the surface. If, however, the interfacial tension is low, the water "wets" the surface, and it tends to spread out in a more or less continuous film over considerable areas and this gives rise to high electrical leakage.

It was found that almost any rubber composition had an adequately low factor of heat conductance, but that extremely few compounds possessed the required inherent

Figure 1. Illustration of mischievous damage to glass insulators

Full text of paper **49-59**, "Rubber Insulators for Pole Lines," recommended by the AIEE communication committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

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Figure 2. Left to right are shown the standard double petticoat glass insulator; R-4 rubber insulator for use on wood pin; R-3 rubber insulator for mounting on spindle of steel pin; R-5 rubber insulator for use on telephone-type short-shank transposition pin; RC-1 rubber insulator for use with Case span-type transposition bracket

"nonwetting" surface characteristic desired for good insulating efficiency under conditions of rain or heavy fog.

Ultimately, a vulcanized rubber compound was developed having a reasonably satisfactory combination of essential qualities. This rubber compound was of the wax-bearing type, and the composition and extent of the wax ingredient and the technique of compounding were important characteristics in its manufacture. The wax component of the mixture blooms, or migrates to the surface, continuously for years, thereby maintaining in service high interfacial tension with water and insuring the desired "nonwetting" characteristic of the insulator; in addition, reasonably self-cleaning characteristics are afforded, and almost complete freedom from surface checking under prolonged sun exposure. This wax component of the rubber compound represents one of the principal features of Western Union patents covering the product.

Two styles of single petticoat rubber insulators, designated as types *R-1* and *R-2*, were designed for force-fit mounting on the spindle of a steel pin. A field trial of the *R-1* insulators showed the desirability of reinforcing the wire groove, while laboratory studies of the *R-2* insulator, which was designed to contain a minimum amount of rubber, indicated that the reduction in size was carried too far. The essential details of these two designs were combined in a third design, called type *R-3*, which is now standard for use with steel pins. A fourth design was tried, moulded so as to provide an inner petticoat, but moulding difficulties were encountered which made the cost of manufacture prohibitive.

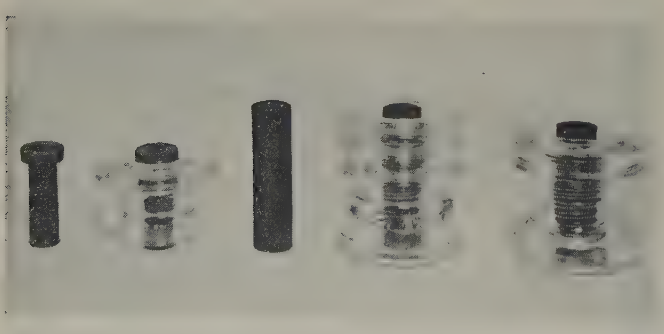

Figure 3. Left to right are shown the RB-1 flange-type rubber bushing; RB-1 rubber bushing in position in glass insulator, used on Case span-type transposition bracket; RB-2 straight-type rubber bushing; RB-2 bushing in position in dead-ending glass insulator; RB-2 bushing in position in power insulator

The design of the type *R-3* insulator is shown in Figure 2, along with other styles of rubber insulators that were developed subsequently for specific purposes. The type *R-4* insulator shown was designed with an inner thread for use on wood pins, and currently is being employed in considerable quantities in the telephone industry. The type *R-5* insulator, designed for use on telephone-type short-shank transposition pin, was developed to meet requirements of two Canadian railroads. The type *RC-1* insulator was designed for use on the Case span type transposition bracket where the expense of replacing a broken glass insulator is sometimes prohibitive. The compound used in the type *R-5* and type *RC-1* insulators had to be modified somewhat to improve its toughness, to enable the insulators to withstand the continuous severe stresses encountered in service.

This latter compound subsequently was adapted for use as bushings in various types of glass insulators, as shown in Figure 3. It was found that this rubber composition not only provided adequate resilience for the assembly, but materially improved its over-all electrical efficiency. The *RB-1* flange-type rubber bushing shown was designed for use with the glass insulator on the Case span-type transposition bracket. The *RB-2* straight-type rubber bushing was designed for the shackle-type glass insulator to replace the lead bushing which normally was used, but which was not entirely satisfactory. The *RB-2* bushing also is shown in position in a glass insulator for use in power work; this combination of rubber bushing and glass insulator is being used to replace porcelain insulators and is an entirely new development in the power industry.

Rubber insulators moulded with these approved compositions definitely have solved the breakage problem, not only in service but also in shipping and handling. In actual tests, with insulators mounted on steel pins, loads that resulted in bending the pins left the rubber insulators unmarked. One such insulator, dropped from a 12-story window to the concrete pavement, was entirely unaffected. Bullets would pass through, but would not shatter the insulators. The smaller projected area made hits less likely, and the lack of any visible evidence on the insulator when struck discouraged its use as a target for marksmen.

The first extensive field installations of rubber insulators on steel pins were made in 1939 and 1940 in a wide variety of areas including Florida, representing severe sunlight exposure; the West Coast along San Francisco Bay, representing a difficult fog area; Nebraska, a heavy wind exposure; and the New York–Philadelphia area, representing a wide diversity of weather conditions varying from dry to fog and heavy rains. Numerous small installations also were made in locations where the breakage of glass insulators was a major consideration.

After six years' service, a number of these insulators were removed from the various areas for rigorous laboratory

inspection, and it was observed generally that the insulators were practically as good as new, except those from the Florida area which showed a slight superficial checking of the rubber. All of these insulators continued to maintain their original toughness and elasticity, as well as their self-cleaning and water-repellent characteristics.

In the heavy wind exposure in Nebraska, it was found that the rubber insulators are capable of satisfactorily supporting the relatively heavy loads resulting from large gauge iron wires. Where the rubber insulators supported number 9 copper wire in this area, the resilience of the rubber materially reduced tie-wire breakage and resulted in fewer fatigue breaks of the line wire.

In the New York–Philadelphia and the West Coast areas, the rubber insulators at critical points of support, such as at corners and terminals, showed no weakening under the severe mechanical strain encountered.

Because the line sections most vulnerable to insulator damage were selected initially for rubber insulator installations, the field reports indicated that the saving in broken glass insulators for the first year more than paid for the rubber insulators, and resulted in reduced material and labor costs. In addition, by eliminating the broken insulators which ordinarily caused increased leakage and wire trouble in wet weather, sustained line insulation was achieved, with consequent increased operating efficiency of the circuits.

The electrical performance of rubber insulators in the various classes of service has exceeded original expectations considerably. Relative insulation resistance characteristics determined from d-c leakage measurements on circuits insulated with rubber and with glass, respectively, are shown by the curves in Figure 4.

In Figure 4, the curves representing Elizabeth–Trenton circuits comprising about 45 miles of open wire (approximately 3,100 insulators per circuit), indicate the average performance, during periods of heavy rain, of two rubber-insulated circuits and two glass-insulated circuits, all installed at the same time, as compared with old glass-insulated circuits that have been in service for 30 years.

These curves show that after the first few months the rubber-insulated circuits develop and maintain about a 100 per cent improvement over "old" glass-insulated circuits in insulating properties. On the other hand, while the new glass-insulated circuits appear to be nearly five times as good as the old glass-insulated circuits and almost twice as good as the rubber-insulated circuits in the early stages of exposure, they deteriorate more rapidly in insulation resistance so that after the first three or four years on the line, they approach the rubber-insulated circuits in insulating characteristics and maintain this equivalent electrical performance on further exposure. Although these curves reveal that the circuits insulated with rubber and "new" glass maintain, on prolonged exposure, a two-to-one superiority over "old" glass-insulated circuits, field reports show no noticeable difference, under normal weather conditions, in the operating performance of any of these circuits, indicating that the old glass insulators still possess adequate insulation.

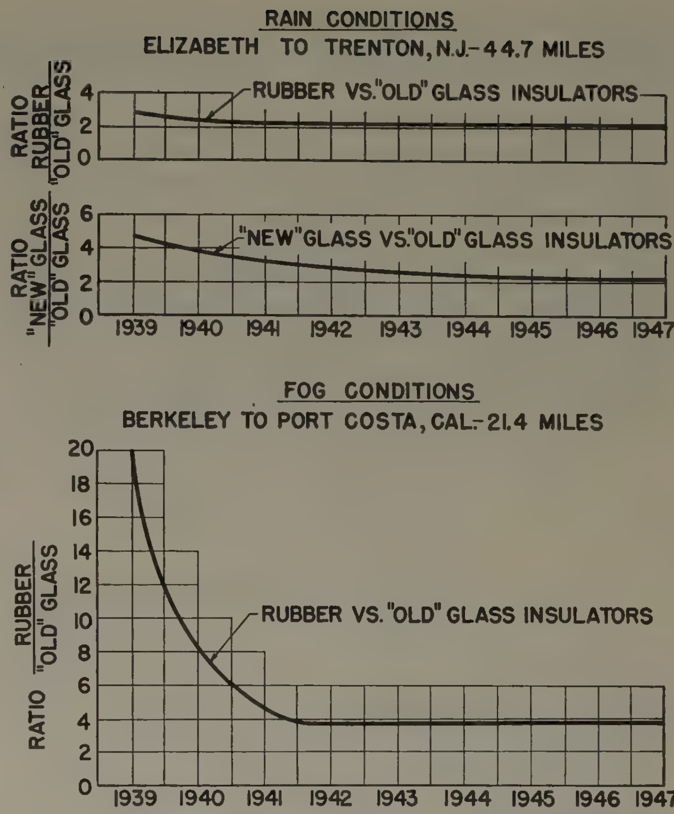

Figure 4. Relative insulation resistance of open wire circuits

In Figure 4, the curve representing Pacific Coast circuits along San Francisco Bay comprising about 22 miles of open wire (approximately 900 insulators per circuit), shows the average performance of two rubber-insulated circuits as compared with old glass-insulated circuits that have been in service for 30 years or more; no "new" glass-insulated circuits were erected in this section when the rubber insulators were installed. This curve indicates that during periods of widespread fog, the rubber-insulated circuits during the first two years of service are 8 to 20 times as good as the old glass-insulated circuits from the standpoint of insulation resistance, and then reach a state of equilibrium in which they appear to maintain a line insulation practically four times as good as old glass-insulated circuits. This relative performance in this area is confirmed also by current field reports which indicate that during periods of adverse weather, when all of the glass-insulated circuits are completely "fog-bound," the rubber-insulated circuits provide reasonably satisfactory operation.

These relatively extensive field tests with the steel-pin-type rubber insulators indicate generally that in normal telegraph service, the electrical efficiency of rubber-insulated circuits in heavy rain exposure can be expected to be about on a par with that of glass-insulated circuits of the same age, and superior to glass-insulated circuits in an area where heavy fog and high humidity are encountered. Similar results have been reported on the use of the wood-pin-type rubber insulators by the telephone industry.

Although no carrier circuits have been insulated as yet exclusively with rubber, short sections have been so equipped, with no apparent change in operating efficiency.

Limited laboratory studies on the relative transmission efficiency of rubber- and glass-insulated circuits at various frequencies indicate that the a-c wet weather losses for both types of circuits are about the same for frequencies up to, and somewhat beyond 30 kc. Because of limited experience with rubber insulators at frequencies appreciably higher than 30 kc, and the fact that at these frequencies electrical losses mount rapidly, it is not possible to say at this time whether a circuit insulated entirely with rubber in this higher frequency range would provide acceptable operating efficiency, but it is believed that a small percentage of rubber insulators in such a circuit would not adversely affect its over-all transmission characteristics.

Rubber insulators never will equal in lasting qualities the more fortunate glass insulators, many of which in their 50 or more years of existence have out-lasted not only the original crossarm on which they were mounted, but also its replacement. However, it is anticipated that the average life expectancy of rubber insulators will be 15 years or more, judging from their performance during the past nine years. Furthermore, their outstanding record of durability and over-all electrical and mechanical efficiency during these nine years warrants their continued use, even if it were not for the determining factor—that rubber insulators are without question the answer to the problem of mischievous breakage.

New International Temperature Scale

On January 1, 1949, the National Bureau of Standards began using the definitions of the International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other scientific and industrial purposes. Based on a draft prepared by members of the bureau staff, the new scale was adopted at Paris by the Ninth General Conference on Weights and Measures in October 1948, and the official text was approved for publication before the end of the year. This is the first revision of the International Temperature Scale since its adoption 21 years ago. The experimental procedures fixing the scale are substantially unchanged; but certain refinements have been incorporated to make the scale more uniform and reproducible.

The experimental difficulties inherent in the measurement of temperature on the thermodynamic scale (an ideal scale based on energy changes in a Carnot cycle) led to the establishment in 1927 of the International Temperature Scale. This scale is based upon six reproducible equilibrium temperatures, or "fixed points," to which numerical values are assigned, and upon specified interpolation formulas relating temperature to the indications of specified standard temperature-measuring instruments. The scale is designed to conform, as nearly as practicable, to the thermodynamic Celsius scale (the Ninth General Conference decided to abandon the designation centigrade and use Celsius instead), as it is now known. At the present time it is possible to obtain values of temperature on the International Temperature Scale more accurately than on any thermodynamic scale.

Since the adoption of the 1927 scale, the increasing precision attained in temperature measurements had made it apparent that some revision was desirable in order that they might be made on a more exactly comparable basis by laboratories in all parts of the world.

The six fixed points of the 1927 scale were the boiling point of oxygen (−182.97 degrees centigrade), the freezing and boiling points of water, the boiling point of sulfur (+444.60 degrees centigrade), the melting point of silver (+960.5 degrees centigrade), and the melting point of gold (+1063 degrees centigrade). From −190 to +660 degrees centigrade, the measure of temperature was based on the indications of a standard platinum resistance thermometer used in accordance with specified formulas. From +660 degrees centigrade to the gold point, a platinum-platinum rhodium thermocouple was the reference instrument; and above the gold point, the optical pyrometer has been standard.

The same fixed points, with one slight modification, are specified in the 1948 scale, and the laboratory procedures for obtaining temperatures between fixed points are essentially the same as those previously used. Only two revisions in the definition of the scale result in appreciable changes in the numerical values assigned to measured temperatures. One of these is the change in the value for the silver point from 960.5 to 960.8 degrees centigrade, which affects temperatures measured with the standard thermocouple. Thus, in the range between 630 and 1,063 degrees centigrade, numerical values of temperature are higher than on the 1927 scale, the maximum difference being about 0.4 degree near 800 degrees centigrade. The adoption of a new value (1.438 centimeter-degrees) for the constant c_2 in the radiation formulas changes all temperatures above the gold point. In the new scale, Planck's radiation formula is specified instead of Wien's for calculating temperatures above the gold point as observed with an optical pyrometer. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change removes the upper limit to the scale formerly imposed by the use of Wien's law.

Another important modification in the scale calls for the use of the standard platinum resistance thermometer as a reference instrument from the oxygen point to the freezing point of antimony (about 630 degrees centigrade), rather than over the range from −190 to +660 degrees centigrade. Also, platinum of higher purity is specified for the standard resistance thermometer and standard thermocouple, and smaller permissible limits are given for the electromotive force of the standard thermocouple at the gold point.

Large Indoor Air-Blast Circuit Breakers

G. E. JANSSON

IN early experiments and studies of the air-blast circuit breaker, the conclusion was reached that no upper limit of interrupting capacity within a reasonably visualized range existed. This conviction was expressed by P. L. Taylor and H. W. Martin in a paper presented at a meeting of the AIEE in New York in 1942. As a matter of fact, it was surmised that whether the arc was drawn axially with the blast or perpendicular to the same, interruption always occurred with the arc axial with the blast. The reason for this appears to be the greater action of the blast on the radially diffused thermal ions when the arc is parallel to and surrounded by the blast.

In the development of the indoor high-power medium-voltage circuit breaker, it is desirable to retain the axial-blast circuit breaker arc-interruption chamber or grid, while combining with it some of the best features of the cross-blast circuit breaker structure, such as the greater ease of design for high-current carrying capacity in the latter by means of multiple bar and finger contacts, and the combination of interrupting and isolating contacts.

Five different interrupting grids were made up and tested. Three of these developed weaknesses at rather low currents. Of the remaining two, one interrupted currents from 500 to 38,200 amperes, and the other interrupted 25 single-phase close-open shots from 500 to 55,000 amperes.

The tests also brought out the fundamental air flow difference between axial- and cross-blast designs. In the former, a pressure peak wave similar to the reflected voltage wave on an open end transmission line occurs in the interrupting chamber on account of the fact that the air flow is stopped until the contacts part; whereas in the latter, the open-to-atmosphere construction results in a pressure dip, however with increased air flow velocity at the arcing contacts. On interruption of a power arc, a zone of high pressure is created surrounding the arc. By increasing the current to a value where this high pressure exceeds the tank pressure and extends over the entire area of the nozzle or outlet, it is evident that the air flow will be stopped and even may reverse its direction. Hence, a high-pressure wave actually may travel from the nozzle to the tank.

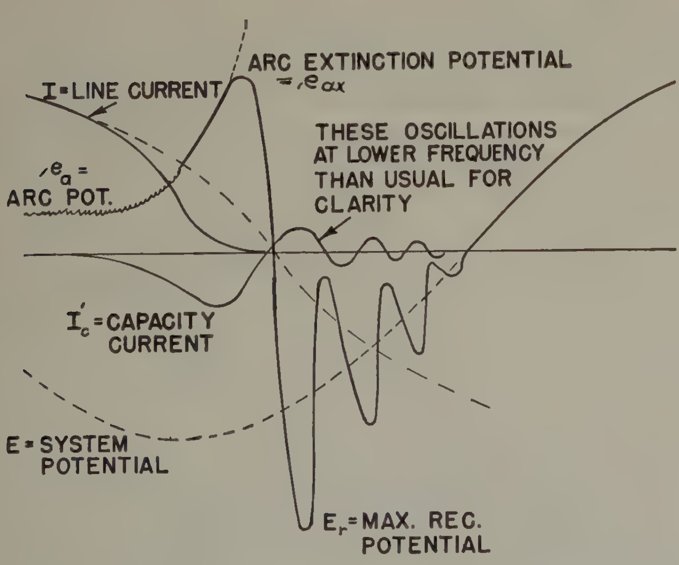

Figure 1. Current and voltage without parallel resistance to arc

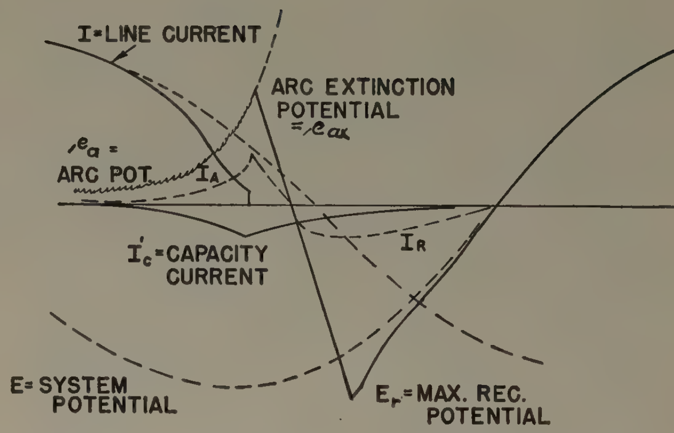

Figure 2. Current and voltage with parallel resistance to arc

The contacts follow the conventional wedge and finger contact type which, with proper dimensioning and configuration with the smallest practical entrance angle and sufficient length to compensate magnetic blow-off forces, are well suitable for closing against high inrush currents.

A parallel resistor, which is cut in parallel with part of the arc during interruption, finally will cause the parallel part of the arc to be extinguished when the arc voltage becomes great enough to force the whole arc current through the resistor, as indicated in Figures 1 and 2. This occurs slightly previous to current zero; since this parallel resistor is many times the short-circuit impedance, the arc then is interrupted practically as in a purely ohmic circuit, resulting not only in a lower rate of voltage rise de_r/dt, but also a lower magnitude, hence increasing the time for dielectric recovery voltage across the circuit breaker gap de_g/dt at faster rate than the recovery voltage rise de_r/dt. The resistor value should be great enough to make the charging current oscillation aperiodic, that is $R \geqq 2\sqrt{L/C}$.

With this parallel resistor of sufficiently low value to limit the recovery voltage to the order of 300 volts per microsecond, the circuit breaker would be practically independent of the system recovery voltage and only dependent upon the physical dimensions and structure of the interrupting device and the air-flow and air-pressure characteristics.

Digest of paper **48-305**, "Large Indoor Power Air Blast Breakers," recommended by the AIEE switchgear committee and approved by the AIEE technical program committee for presentation at the Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Scheduled for publication in AIEE *TRANSACTIONS*, volume 67, 1948.

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Head End Power on Railroad Passenger Trains

H. H. HANFT

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THE IDEA of concentrating electric energy generation at one point in a train, on or behind the locomotive, becomes increasingly attractive with the increase in electric loads on modern passenger cars. The advantages and disadvantages of head end power against those of the conventional d-c axle generator storage battery equipments have been considered. In favor of head end power were simplicity of installation and maintenance, reliability, and elimination of parasitic axle generator drag. The principal argument against head end power lay in its lack of operating flexibility. All cars in such a train must be wired for trainline operation, so that no other cars can be added.

However, drastic increases in power requirements have posed serious problems. As a result, the railroads changed from 32-volt to 64- and 110-volt batteries so that ampere loads and cable sizes could be reduced. If batteries are to be kept up to charge, 50 per cent excess generator capacity should be provided. With a 20-kw load, a 30-kw axle-driven generator consumes approximately 50 horsepower at the rail. Fifteen such cars in a passenger train consume 750 rail horsepower, which must be provided by the locomotive. This parasitic drag means a substantial increase in motive power.

The present high-capacity d-c systems impose complex maintenance problems. The increase in battery voltage means more cells to flush and check, and more connections to maintain. The large generators and numerous commutator-type motors of varying sizes require regular inspection and maintenance of commutators and brushes. These considerations led to the negotiation for a-c head end power.

Concentrating power generation at one point in a train entails two main functions: power generation in the power car, and power distribution throughout the train. One power system proposed was based on the use of two Diesel engine generators carried in a power car directly behind the locomotive. Each engine was rated at 1,000 horsepower at normal governed operating speed of 720 rpm. Directly connected to each engine was a generator rated at 650 kw, three phase, 60 cycles, 480 volts, at 85 per cent power factor. Frequency regulation was maintained by the engine governor. Voltage regulation at varying loads was achieved by dual excitation of an overhung exciter coupled directly to the main generator shaft. The main field of the exciter was connected across a 64-volt battery and provided no-load generator excitation. The auxiliary exciter field drew current from a 3-phase rectifier served by current transformers connected into the main generator output leads. Varying directly with main generator load, the exciter auxiliary field maintained main generator voltage regulation at varying loads.

The bus and cable structure in the power car was arranged so that either generator could be switched to the two power trainlines running the length of the train. Three electically operated shockproof air circuit breakers, actuated by a selector switch, made the connection.

Each car in the train was to be fitted with two 3-phase 3-wire power cable circuits terminating in disconnect boxes at the ends of the car. Each leg of each circuit consisted of two 600-volt insulated cables. Flexible cable power jumpers, fitted with heads to mate with the disconnect boxes, carried power from car to car. At a calculated load of 1,000 kw, 90 per cent power factor, voltage regulation at the end of an 18-car train was 5.3 per cent, or 25 volts. In starting up a train, the power car attendant closed power car circuit breakers, applying voltage to the train line. Circuit breakers on each car tapped the trainline to energize car circuits. Control was provided to prevent all cars in the train from cutting in simultaneously, as a matter of main generator protection.

Within each car, both trainlines were tapped by 3-point terminal blocks located in housings under the car. Contactors connected the trainlines to the 480-volt water-heating circuits, and to a 3-phase $37^1/_2$-kva dry-type transformer which supplied 125- and 216-volt power to motor, lighting, battery charging, auxiliary, and control circuits. On dining cars, a duplicate transformer served the all-electric food storage compartments and cooking equipment.

Each car also carried a small 16-cell battery of 176-ampere-hour capacity to provide emergency lighting and control power at 32 volts. The battery was charged by a 2-rate selenium battery charging rectifier. The battery duty cycle was extremely light, as the battery was kept fully charged except under emergency conditions.

The car heating system included finned heating surfaces, which received power-circulated hot liquid from a thermostatically-controlled heat exchanger of the immersion type. The heat exchanger had a capacity of 40 kw in 480-volt immersion heaters.

All motors on the car were of the 3-phase, 220- or 110-volt squirrel-cage type, with sealed bearings, requiring extremely little maintenance or inspection. The air conditioning compressor motors were hermetically sealed, with windings cooled by refrigerant vapor in the closed cooling circuit. The water cooler compressor motor, likewise, was hermetically sealed.

The power car carried at the head end of the train weighs approximately 300,000 pounds. The present net weight on 18 cars is approximately 174,000 pounds, which deducted from the 300,000-pound weight of the power car leaves a net train weight deficit of 126,000 pounds, the weight of one average modern car. The power expended in hauling this equivalent of one extra car is far less than the 750 rail horsepower saved by eliminating axle generator drag.

Digest of paper 48-302, "Head End Power on Railroad Passenger Trains," recommended by the AIEE land transportation committee and approved by the AIEE technical program committee for presentation at the AIEE Midwest general meeting, Milwaukee, Wis., October 18–22, 1948. Not scheduled for publication in AIEE *TRANSACTIONS*.

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Electromagnetic Induction

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THE TWO most widely used laws of electromagnetic induction are the flux-linking law, as given in rationalized meter-kilogram-second units

$$\mathcal{E} = -\frac{d\phi}{dt} \tag{1}$$

which states that the electromotive force $\mathcal{E}$ induced in a circuit is equal to the negative time derivative of the magnetic flux ϕ linking the circuit, and the flux-cutting law

$$d\mathcal{E} = \boldsymbol{v} \times \boldsymbol{B} \cdot \boldsymbol{dl} \tag{2}$$

which states that the electromotive force across an element $\boldsymbol{dl}$ moving with a velocity $\boldsymbol{v}$ through a magnetic field $\boldsymbol{B}$ is equal to their triple scalar product. Upon integrating over the circuit, this gives the induced electromotive force

$$\mathcal{E} = \int \boldsymbol{v} \times \boldsymbol{B} \cdot \boldsymbol{dl} \tag{3}$$

For uniform and mutually perpendicular B, v, and l the flux-cutting law is simply

$$\mathcal{E} = Bvl \tag{4}$$

The flux linking law, $\mathcal{E} = -d\phi/dt$, and the flux cutting law, $\mathcal{E} = Bvl$, often erroneously are considered as merely different ways of expressing the same phenomena. This article attempts to dispel the confusion surrounding the subject of electromagnetic induction.

In many simple cases both induction laws lead to the same value of induced electromotive force. This has been the source of much confusion, since it then appears that the two induction laws are merely alternate expressions for the same thing, or that one of them is completely general and the other merely a special case. The most outstanding by-products of this misunderstanding are the innumerable d-c generators without moving contacts which have been invented (and do not work). It is a simple matter to construct examples in which the correct value of induced electromotive force is given by: (*a*) equation 1 and not by equation 3, (*b*) equation 3 and not by equation 1, (*c*) the sum of equations 1 and 3, neither equation 1 nor equation 3 nor the sum of the two.

There are actually two kinds of electromagnetic induction: motional and transformer induction. The electromotive force generated by motion through a constant magnetic field is a pure case of motional induction. The electromotive force generated in a stationary circuit by the variation of the magnetic field with time is a pure case of transformer induction. In general, both types of induction are involved in a given case. One source of confusion is that there is *not* a one to one correspondence between the two types of induction and the two common induction laws.

The flux-cutting law gives exactly the electromotive force caused by motional induction. The flux-linking law sometimes includes both types of induction and sometimes does not. Hence, if the flux-cutting law is used alone, the transformer induction will be lacking. If the flux-linking law is used alone, part or all of the motional induction will be lacking. If both laws are used together, part or all of the motional induction may be counted twice, and sometimes the flux-linking law calls for an electromotive force when there is none at all. The rule for foolproof application of the flux-linking law, which does not seem to have been enunciated previously, will be given later. The case in which the flux-linking law calls for an induced electromotive force which does not exist have been classified by one means or another as a substitution of circuit. It has been stated *ad hoc*, as a fundamental principle, that "no voltage can be induced by a substitution of circuit."[1] Actually, this will appear as an obvious deduction from the fundamentals discussed in this article.

Another source of confusion, rather less well recognized, can be traced back to the choice of "field theory" underlying the analysis of the problem. When the source of the magnetic field is moving, the question arises as to what the motion of the magnetic field itself is. Does the magnetic field move as if rigidly attached to its source, does it remain stationary while the source moves through its own field, does it behave with a motion in between these two, or is there some entirely different alternative? Each different answer is the basis of a different field theory. The two most used theories for the solution of ordinary engineering problems are the moving field theory, which assumes that the field moves as if rigidly attached to its source, and the stationary field theory, which assumes that the field remains fixed while the source moves through its own field. In addition, there is, of course, relativity theory in which the field is not an entity which can be characterized by the property of motion. The purpose of this article is to clarify the phenomena of electromagnetic induction and not to discuss the scope and limitations of the various field theories; all the examples treated here fall well within the scope of the moving and stationary field theories.

The total induced electromotive force is a measurable quantity and, as such, any correct theory must lead to the same value. The total electromotive force is the sum of electromotive forces caused by both motional and transformer induction. The defining concepts and formulas for transformer and motional induction are the same for both

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types of field theories. However, calculated by different field theories, in general, they will have different values. (An analogy about distance between two fixed points in two different co-ordinate systems may be helpful. While the individual co-ordinate differences are different in the two co-ordinate systems, the distance itself is variant.) Hence, for a clear understanding of motional and transformer induction, the underlying difference between field theories must be understood. For successful solution of a problem, it is essential not to change field theories used in the middle of the problem. In some circles it is believed that presence of transformer or motional induction depends merely on the choice of reference axis.[1] That this is erroneous will become obvious from the examples treated. The change, if any, is actually caused by a change of theory and not a change of axis.

PARADOXES

Unipolar Generator. The Faraday disk is one of the oldest and best known of the experiments which sharply differentiate between the flux-cutting and flux-linking laws. This form of unipolar generator consists of a circular conducting disk rotating in a constant uniform magnetic field perpendicular to it, as shown in Figure 1. A voltmeter and leads complete the circuit through brush *A* on the conducting axle and brush *B* on the rim. Calculating the induced electromotive force by means of the flux-cutting law, equation 3:

$$\mathcal{E}=\omega B\int_0^R r dr \tag{5}$$

$$\mathcal{E}=(1/2)\omega BR^2 \tag{6}$$

Using the flux-linking law, equation 1, however, leads to

$$\mathcal{E}=0 \tag{7}$$

because there is no flux-linking the circuit. Even if the generator were tilted so that the flux linked the circuit, the time derivative is zero and hence there is still no induced electromotive force. Which is correct? Experiment verifies equation 6, hence this example is a pure case of motional induction. It is ironical that the induction law attributed to Faraday does not hold for his own device.

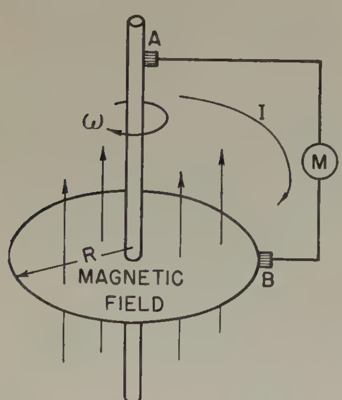

Figure 1. Faraday's disk

D-C Generator.[2] Consider the scheme shown in Figure 2. The conductor in the magnet air gap swings back and forth like a trapeze bar about the horizontal leads which are connected to the meter. Its velocity is given by $v=v_m \cos \omega t$. The amplitude of swing is taken as small, so that the error made by considering the velocity to be horizontal is negligible. An alternating current is supplied to the exciting coil so that the magnetic field in the air gap is $B=B_m \cos \omega t$ and is uniform over the path of swing. The field in the gap is positive when it is directed upward. The velocity of the bar is positive when swinging from left to right. When the bar is swinging to the right, the magnetic field is in the upward direction. When the bar reaches the right extremity of its swing, the magnetic field has decreased to zero. The direction of the field reverses at the same time as the velocity of the bar. Therefore, on the backswing the bar travels through a magnetic field directed downward; as a result, the electromotive force induced in the wire is always in the same direction, thereby giving a pulsating direct voltage.

The motionally induced electromotive force, from the flux-cutting law, equation 4, is

$$\mathcal{E}=B_m v_m l \cos^2 \omega t \tag{8}$$

or

$$\mathcal{E}=1/2 B_m v_m l + 1/2 B_m v_m l \cos 2\omega t \tag{9}$$

Hence this d-c generator has a constant voltage component of $1/2 B_m v_m l$ and a double-frequency a-c component of $1/2 B_m v_m l \cos 2\omega t$. It is interesting to notice that there is an alternating electromotive force over and above the constant electromotive force generated by motional induction.

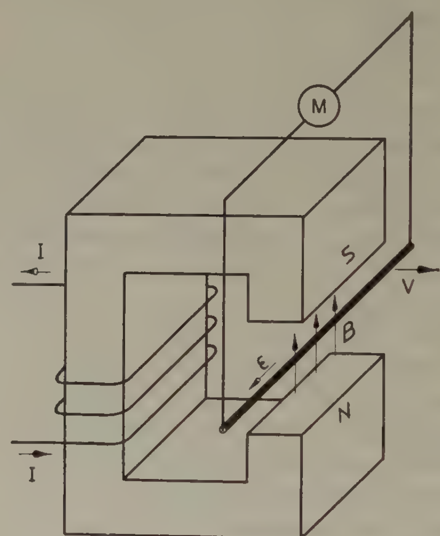

Figure 2. D-c generator

Let us calculate the induced electromotive force by the flux-linking law

$$\phi=\mathbf{B}\cdot\mathbf{A} \tag{10}$$

$$\phi=(B_m \cos \omega t)(lr)\cos\theta \tag{11}$$

$$\phi=B_m lr \cos \omega t \sin \omega t \tag{12}$$

$$\mathcal{E}=B_m lr\omega\,(\cos^2 \omega t-\sin^2 \omega t) \tag{13}$$

$$\mathcal{E}=B_m v_m l \cos 2\omega t \tag{14}$$

This is not in agreement with results of the flux-cutting law, equation 9. Experiment verifies that the flux-linking law gives the correct result.

It is interesting to note that Maxwell's equation for transformer induction

$$\mathcal{E}=-\int\int\frac{\partial \boldsymbol{B}}{\partial t}\cdot d\boldsymbol{S} \tag{15}$$

gives

$$\mathcal{E}=-1/2B_mv_ml+1/2B_mv_ml\cos 2\,\omega t \tag{16}$$

as the electromotive force generated by transformer induction. There is a constant component of induced electromotive force caused by transformer action. If this electromotive force is omitted, this device appears to be a d-c generator without moving contacts. The same, of course, would be true if only the transformer induction were considered. If the electromotive force caused by both types of induction are added together, however, the d-c components cancel and the a-c components add to give the result obtained from the flux-linking law.

Commutating Magnet. Consider a magnet with a loop around one leg, as shown in Figure 3. In the loop is a voltmeter M. The upper end of the loop is completed by means of a pair of spring clips which are capable of acting as a pair of sliding contacts. The magnet is moved upward, separating the spring contacts and completing the circuit through the magnet. The magnet continues to move upward until the magnet and its flux are separated from the loop.

Before calculating the induced electromotive force, if any, we must decide whether to use the moving field theory or the stationary field theory, since the source of the field, the magnet, is in motion. For the moment let us avoid this decision by considering the equivalent problems of holding the magnet stationary and moving the meter, leads, and spring clip instead. The flux linking the circuit is

$$\phi=Blx \tag{17}$$

The flux-linking law, equation 1, gives

$$\mathcal{E}=-Bl\frac{dx}{dt} \tag{18}$$

or

$$\mathcal{E}=Blv \tag{19}$$

The flux-cutting law, equation 4, gives

$$\mathcal{E}=0 \tag{20}$$

because the portion of the circuit in the magnetic field is not moving and the moving portion is not in the magnetic field. Since the magnetic field does not vary with time, there is no transformer induction; this is pure motional induction, which, in this case, is zero. Although the flux-linking law states that there is an induced electromotive force, experiment verifies that there is none.[3] The breakdown of the flux-linking law in this case has been excused and dismissed by the statement "no voltage can be induced by a substitution of circuit."[1] The exact cause of this failure will be explained later.

Let us now return to the original problem with the magnet moving as shown in Figure 3. First, we will analyze the problems using the moving field theory and, second, with the stationary field theory. The moving field theory calls for the field to move as if rigidly attached to the magnet. Therefore, the portion of the circuit in the magnetic field, the magnet leg itself, has no velocity through the magnetic field and, hence, there is no motional induction, equation 20. The flux-linking law again gives the erroneous result of equation 19. Analyzing the problems with the stationary field theory is more complex. Here the field is assumed to be stationary, so that the magnet leg actually moves

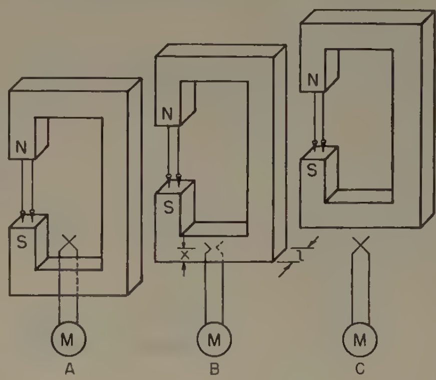

Figure 3. Commutating magnet

through its own magnetic field. A motionally induced electromotive force, given by equation 4, is produced and has the value

$$\mathcal{E}=Bvl \tag{21}$$

The magnetic field is building up from zero to full strength in the leading edge of the magnet leg and collapsing from full strength to zero in the trailing edge of the leg. Since the trailing edge is inside the circuit, the time variation of magnetic field at that location causes a transformer induced electromotive force in the circuit and as given by equation 15 is

$$\mathcal{E}=-Bvl \tag{22}$$

The total induced electromotive force is zero since the transformer component exactly cancels the motional component. Here again the flux-linking law, which is insensitive to choice of theory, gives the erroneous result given by equation 19.

Linear Motion Inductor.[4] A cylindrical metal tube moving axially along a straight conductor, carrying a steady current, is shown in Figure 4. On the inner and outer surfaces are two fixed brushes making contact with the cylinder in order to complete the voltmeter circuit through the cylinder. Will the induced electromotive force depend on the permeability of the cylinder?

First calculate the induced electromotive force with the flux-linking law. Let $\boldsymbol{B}_o$ be the magnetic field in free space, $\boldsymbol{B}$ the field in the cylinder, and $\boldsymbol{B}_i$ the component of the field contributed by the atoms composing the cylinder. Then $\boldsymbol{B}=\boldsymbol{B}_o+\boldsymbol{B}_i=\mu\boldsymbol{B}_o$. The flux linking the circuit is

$$\phi=\int\int\boldsymbol{B}\cdot d\boldsymbol{S} \tag{23}$$

$$\phi=x\int_{r_1}^{r_2}Bdr+(l-x)\int_{r_1}^{r_2}B_odr+C \tag{24}$$

$$\phi=x\int_{r_1}^{r_2}\frac{\mu I}{2\pi r}\,dr+(l-x)\int_{r_1}^{r_2}\frac{I}{2\pi r}\,dr+C \tag{25}$$

$$\phi=\frac{I}{2\pi}\ln\frac{r_2}{r_1}(\mu x-x+l)+C \tag{26}$$

The flux-linking law then gives

$$\mathcal{E}=-\frac{I}{2\pi}(\mu-1)v\ln\frac{r_2}{r_1} \tag{27}$$

Next calculate the induced electromotive force by the flux-cutting law, equation 3. According to the moving field theory, the field $\boldsymbol{B}_i$ moves with the cylinder and the field $\boldsymbol{B}-\boldsymbol{B}_i=\boldsymbol{B}_o$ does not. Hence the moving elements of

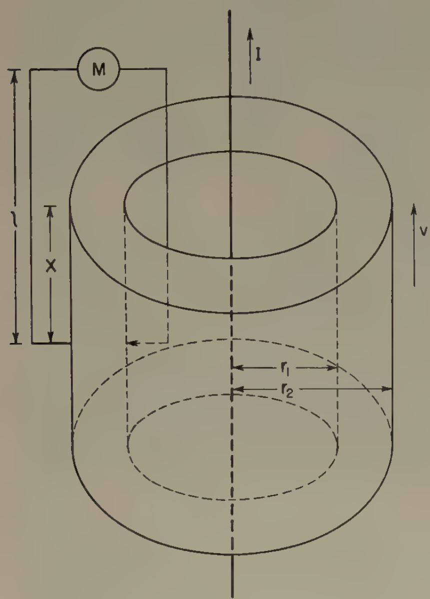

Figure 4. Linear motion inductor

the circuit only move through the field $\boldsymbol{B}_o$ and the motionally induced voltage is, by equation 3

$$\mathcal{E}=v\int_{r_1}^{r_2}B_o dr \tag{28}$$

$$\mathcal{E}=\frac{I}{2\pi}v\ln\frac{r_2}{r_1} \tag{29}$$

Since there is no time variation of magnetic field there is no transformer induction by equation 15. If the stationary field theory is used to analyze this example, the transformer induction due to the building up of the field from $\boldsymbol{B}_o$ to $\boldsymbol{B}$ in the leading edge of the cylinder is given by equation 15 as

$$\mathcal{E}=\frac{I}{2\pi}(1-\mu)v\ln\frac{r_2}{r_1} \tag{30}$$

The motional induction is given by equation 3 as

$$\mathcal{E}=\frac{\mu I}{2\pi}v\ln\frac{r_2}{r_1} \tag{31}$$

Addition of equation 30 and 31 gives the total electromotive force based on the stationary field calculations and is exactly the same as equation 29, the total electromotive force as calculated by the moving field theory. Experiment verifies equation 29, and reveals another failure of the flux-linking law.

ELECTROMAGNETIC INDUCTION THEORY

Forces. To calculate the behavior of an electrodynamic system, the forces exerted on charges must be known. Charges experience certain forces which are related to their magnitudes together with their

(*a*). Positions.
(*b*). Velocities.
(*c*). Accelerations.

The differential formulas for these forces are, respectively,

$$d^2\boldsymbol{F}_1=\frac{dq_1\,dq_2\,\boldsymbol{r}}{4\pi\epsilon r^3} \tag{32a}$$

$$d^2\boldsymbol{F}_1=\frac{\mu dq_1dq_2\boldsymbol{v}_1\times(\boldsymbol{v}_2\times\boldsymbol{r})}{4\pi r^3} \tag{32b}$$

$$d^2\boldsymbol{F}_1=-\frac{\mu dq_1dq_2\boldsymbol{a}_2}{4\pi r} \tag{32c}$$

where $d^2\boldsymbol{F}_1$ is the differential force exerted on charge dq_1 by charge dq_2, $\boldsymbol{v}_1$ is the velocity of dq_1, $\boldsymbol{v}_2$ is the velocity of dq_2, $\boldsymbol{a}_2$ is the acceleration of dq_2, and μ is the permeability. When the discrete charges are sufficiently concentrated, the relation

$$I\boldsymbol{dl}=\boldsymbol{v}dq \tag{33}$$

allows equations 32b and 32c to be expressed in the normal form involving current elements

$$d^2\boldsymbol{F}_1=\frac{\mu I_1I_2\boldsymbol{dl}_1\times(\boldsymbol{dl}_2\times\boldsymbol{r})}{4\pi r^3} \tag{34b}$$

$$d^2\boldsymbol{F}_1=-\frac{\mu dq_1\boldsymbol{dl}_2}{4\pi r}\frac{\partial I_2}{\partial t} \tag{34c}$$

Charges also experience forces due to radiation, thermal, chemical, and contact phenomena. As these are outside the scope of the subject of this article they will not be discussed here.

Fields. Fields may be considered as mathematical constructs. Their purpose is to simplify the determination of the forces experienced by charged particles. For each type of force there is a type of field suitable for its specification. These are, respectively,

(*a*). Electrostatic field.
(*b*). Magnetic field.
(*c*). Vector-potential field.

The differential formulas for these fields are, respectively

$$d\boldsymbol{E}=\frac{dq_2\boldsymbol{r}}{4\pi\epsilon r^3} \tag{35a}$$

$$d\boldsymbol{B}=\frac{\mu dq_2\boldsymbol{v}_2\times\boldsymbol{r}}{4\pi r^3} \tag{35b}$$

$$d\boldsymbol{A}=\frac{\mu dq_2\boldsymbol{v}_2}{4\pi r} \tag{35c}$$

or in terms of current elements

$$d\boldsymbol{B}=\frac{\mu I_2\boldsymbol{dl}_2\times\boldsymbol{r}}{4\pi r^3} \tag{36b}$$

$$d\boldsymbol{A}=\frac{\mu I_2\boldsymbol{dl}_2}{4\pi r} \tag{36c}$$

By expressing the force formulas of the preceding section in terms of the foregoing fields (and integrating once), consider-

able simplification of formulas is obtained. The force formulas are then, respectively

$$dF_1 = dq_1 E \tag{37a}$$

$$dF_1 = dq_1 v_1 \times B \tag{37b}$$

$$dF_1 = -dq_1 \frac{\partial A}{\partial t} \tag{37c}$$

The "field concept" allows the "divide and conquer" technique to be applied to the problem of finding the forces.

Electromagnetic Induction. When the forces which are exerted on charged particles by magnetic and vector-potential fields are explained in terms of an (hypothetical) electric field, this electric field is said to be generated by electromagnetic induction. In other words, if a charged particle experiences a force, we may consider that this force is caused by an electric field. If the force is actually caused by a magnetic or vector-potential field, we may consider this equivalent electric field as being generated by electromagnetic induction. This definition reduces all the force formulas to the form

$$dF = dq E \tag{38}$$

where the magnetic field is replaced by an equivalent electric field given by

$$E_M = v \times B \tag{39}$$

and the vector-potential field is replaced by an equivalent electric field given by

$$E_T = -\frac{\partial A}{\partial t} \tag{40}$$

The reduction of all fields to equivalent electric fields

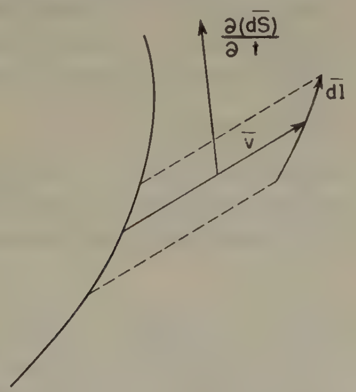

Figure 5. Differential area swept out by motion of circuit element

enables the force to be calculated from one resultant field. The total electric field is then given by

$$E = E_s + E_M + E_T \tag{41}$$

Substituting equations 39 and 40 into equation 41 gives

$$E = E_s + v \times B - \frac{\partial A}{\partial t} \tag{42}$$

(This formula is actually the Lorentz force formula for a unit charge, which physicists usually write as $F = E + v \times B$. The E of Lorentz's formula is the $E_s - \frac{\partial A}{\partial t}$ of the equation and is written out for the purpose of emphasizing the conceptual basis.)

E_s is the electric field given by

$$E_s = -\nabla \psi \tag{43}$$

Where ψ is the scalar potential, E_M is the electric field generated by motional induction, and E_T is the electric field generated by transformer induction.

Transformer Induction. In a case of pure transformer induction there is no motion of material bodies. The formulation of this type of induction is given by

$$E_T = -\frac{\partial A}{\partial t} \tag{40}$$

Transformer induction may be formulated in terms of the

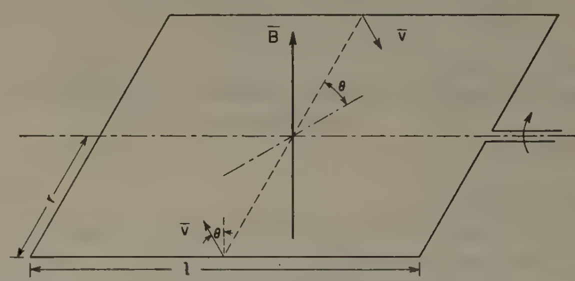

Figure 6. Rotating loop in a constant uniform magnetic field

magnetic field since the vector-potential and magnetic fields are intimately related as follows

$$B = \nabla \times A \tag{44}$$

Taking the curl of both sides of equation 40, permuting the ∇x with $\frac{\partial}{\partial t}$, and substituting equation 44 gives

$$\nabla \times E_T = -\frac{\partial B}{\partial t} \tag{45}$$

which is simply Maxwell's differential formulation of Faraday's induction law. Integrating both sides of equation 45 over the surface bounded by a circuit and transforming the left hand side by Stoke's theorem gives

$$\oint E_T \cdot dl = -\int\int \frac{\partial B}{\partial t} \cdot dS, \tag{46}$$

which is Maxwell's integral formulation of Faraday's induction law. The electromotive force generated by transformer induction is the line integral of E_T

$$\mathcal{E}_T = \int E_T \cdot dl \tag{47}$$

In terms of the vector potential it is

$$\mathcal{E}_T = -\int \frac{\partial A}{\partial t} \cdot dl \tag{48}$$

In terms of the magnetic field it is

$$\mathcal{E}_T = -\int\int \frac{\partial B}{\partial t} \cdot dS \tag{15}$$

Note that the formulation in terms of the magnetic field can give only the total induced electromotive force in circuits which are essentially closed loops. The vector-poten-

tial formulation is capable of giving the voltage induced in any individual element of a circuit.

Motional Induction. In a case of pure motional induction there is no variation of magnetic field with time. The formulation of this type of induction is given by

$$\boldsymbol{E}_M=\boldsymbol{v}\times\boldsymbol{B} \tag{39}$$

This law was derived by Lorentz from the force formula of

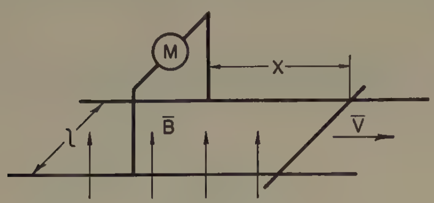

Figure 7. Example of motional induction covered by the combined formula

Biot and Savart.

The electromotive force generated by motional induction is the line integral of $\boldsymbol{E}_M$

$$\mathcal{E}_M=\int \boldsymbol{E}_M\cdot d\boldsymbol{l} \tag{49}$$

$$\mathcal{E}_M=\int \boldsymbol{v}\times\boldsymbol{B}\cdot d\boldsymbol{l} \tag{50}$$

A Combined Induction Law. In the general problem, both types of induction, transformer and motional, occur. It is therefore convenient to have both types combined in one formula.

The total electric field intensity due to both types of induction is the sum of equations 39 and 40

$$\boldsymbol{E}=\boldsymbol{v}\times\boldsymbol{B}-\frac{\partial \boldsymbol{A}}{\partial t} \tag{51}$$

The line integral of the induced electric field intensity along a circuit gives the total electromotive force induced in the circuit, which is

$$\mathcal{E}=\int_a^b \boldsymbol{v}\times\boldsymbol{B}\cdot d\boldsymbol{l}-\int_a^b \frac{\partial \boldsymbol{A}}{\partial t}\cdot d\boldsymbol{l} \tag{52}$$

This is the general formula for the induced voltage in a circuit. It is when this general form is put into special forms that paradoxes arise. These are caused by ignorance or violation of the limiting restrictions imposed by the transformation into the special form. If the second integral in equation 52 is put in terms of the magnetic field, the equation is immediately restricted to closed loop circuits and becomes

$$\mathcal{E}=\oint \boldsymbol{v}\times\boldsymbol{B}\cdot d\boldsymbol{l}-\iint \frac{\partial \boldsymbol{B}}{\partial t}\cdot d\boldsymbol{S} \tag{53}$$

Although we have one formula here, it is essentially no simpler than using the individual formulas for $\mathcal{E}_M$ and $\mathcal{E}_T$. To obtain a simpler expression, both terms must be combined under one integral sign.

Transforming the first term to an integral over the same surface as the second term by means of Stoke's theorem gives

$$\mathcal{E}=-\iint\left[\frac{\partial \boldsymbol{B}}{\partial t}-\nabla\times(\boldsymbol{v}\times\boldsymbol{B})\right]\cdot d\boldsymbol{S} \tag{54}$$

The right-hand side of the following vector integral theorem for the time rate of change of the flux through a moving area

$$\frac{d}{dt}\iint \boldsymbol{B}\cdot d\boldsymbol{s}=\iint\left[\frac{\partial \boldsymbol{B}}{\partial t}+\boldsymbol{v}\nabla\cdot\boldsymbol{B}-\nabla\times(\boldsymbol{v}\times\boldsymbol{B})\right]\cdot d\boldsymbol{S} \tag{55}$$

reduces (except for the minus sign) to the right-hand side of equation 54 since

$$\nabla\cdot\boldsymbol{B}=0 \tag{56}$$

Substituting equation 55 into equation 54 gives

$$\mathcal{E}=-\frac{d}{dt}\iint \boldsymbol{B}\cdot d\boldsymbol{S} \tag{57}$$

which is F. E. Neumann's law of induction.

The magnetic flux linking the circuit is given by the following equation

$$\phi=\iint \boldsymbol{B}\cdot d\boldsymbol{S} \tag{58}$$

Substituting this into Neumann's formula gives

$$\mathcal{E}=-\frac{d\phi}{dt} \tag{1}$$

Strangely enough, this is the form in which Faraday's flux-linking law is normally presented. It is of significance to note that Maxwell's formulation of Faraday's law, equation 15, does not include motional induction.

In order to obtain the limitations on this combined formula, equation 1, let us examine in detail the meaning of the first integral in equation 52.

Rearranging the integral gives

$$\mathcal{E}_M=\int_a^b \boldsymbol{B}\cdot\boldsymbol{v}\times d\boldsymbol{l} \tag{59}$$

As shown in Figure 5, $\boldsymbol{v}\times d\boldsymbol{l}$ is the differential area swept out per unit time by an element of the circuit. This transformation states that all motion resulting in the generation

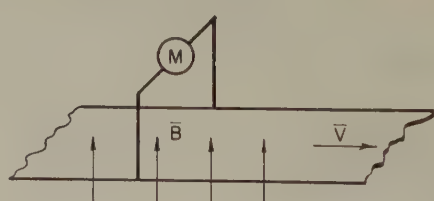

Figure 8. Example of motional induction not covered by the combined formula

of electromotive force changes the path of integration. The path of integration must be taken as moving with the material substance composing it, otherwise the electric fields experienced by the charged particles of the material will not be the same as the electric fields taken in the integration. All fields generated in reference frames other than the reference frame of the material may just as well be fictional, because there is nothing to observe their effect. Only the electric fields experienced by the charged particles produce an observable effect, and in order to calculate *these* fields, the

motion of the paths of integration must be identical with the motion of the material comprising this path at the instant considered.

This point must be kept in mind because it is the basis of the misapplication of the flux-linking (or combined) induction law. This combined induction law is applicable to all closed circuits of constant or changing shape, moving in any way through a constant or changing magnetic field, with sliding contacts or without, provided that the motion of every element of the paths of integration is identical with the motion of the matter comprising that path at the instant considered. To illustrate this limitation, consider Faraday's disk, shown in Figure 1: The radius of the disk from the center to the brush on the rim is the path of integration and it does not move with the material comprising the path. The flux-linking law, therefore, is not applicable to this case.

Examples Fostering Confusion. In the majority of elementary text books all induction is implied to be merely one type of phenomena, even though this is not explicitly stated. The two formulas

$$\mathcal{E} = -\frac{d\phi}{dt} \tag{1}$$

$$\mathcal{E} = Bvl \sin\theta \tag{60}$$

are presented as two different ways of expressing the same thing. This implication is usually substantiated by deriving one from the other and by solving problems which give the same result from both formulas.

One example usually given is the rotating coil in a constant uniform magnetic field shown in Figure 6.

Equation 60 gives directly

$$\mathcal{E} = 2Bvl \sin\theta \tag{61}$$

Equation 1 gives

$$\mathcal{E} = -\frac{d}{dt}[2lrB\cos\theta] \tag{62}$$

$$\mathcal{E} = 2\, Br\dot{\theta}l \sin\theta \tag{63}$$

$$\mathcal{E} = 2Bvl \sin\theta \tag{64}$$

which is identical to equation 61.

Another example usually given is the wire moving through a constant uniform magnetic field with its ends in sliding contact with two long parallel wires as shown in Figure 7.

Equation 60 gives directly

$$\mathcal{E} = -Bvl \tag{65}$$

Equation 1 gives

$$\mathcal{E} = -\frac{d}{dt}(Blx) \tag{66}$$

$$\mathcal{E} = -Blv \tag{67}$$

which is identical to equation 65.

It is unfortunate that the equivalence of these two formulas is stressed by the application of the foregoing technique because it leads to the formation of two schools of thought (both wrong!). One group believes all induction phenomena can be handled with the flux-cutting law, while another believes that the flux-linking law is all-inclusive. Adherents of these two schools go to extremes in the invention of *ad hoc* explanations to bring all induction phenomena within the scope of their equation.[5]

Examples Avoiding Confusion. It would be a good principle if problems bringing out the difference between the two formulas were given instead of special problems emphasizing similarity. If in the foregoing two problems, a time varying magnetic field were given instead of a constant one, the flux-cutting law no longer would give the correct answer but the flux-linking law would. With constant magnetic fields both examples are pure cases of motional induction but with variable fields they have both motional and transformer induction. The second problem, if altered slightly by substituting a long conducting strip moving with a velocity $\boldsymbol{v}$ in place of the long parallel wires and cross wire as shown in Figure 8, provides a simple example in which the flux-linking law is no longer applicable and in which the correct answer is provided by the flux-cutting law.

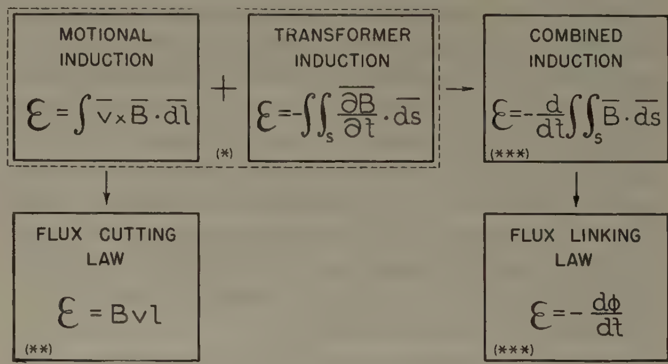

Figure 9. Relation between the induction laws

* *Completely general when combined*

** *Flux must be uniform, and B, v, and l must be mutually orthogonal*

*** *Motion of material and path of integration must be identical*

SUMMARY

The relationship between the various induction laws is summarized in Figure 9. Only the combined use of both motional and transformer induction (both inside the large dotted rectangle) will guarantee validity of results in all cases of induction. When using any of the restricted laws external to the dotted rectangle, care must be used to avoid violation of restrictions incident to such law (as noted in parenthesis).

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Microwave Channels for Power System Applications

AN AIEE COMMITTEE REPORT

THE MICROWAVE SYSTEM is a very-high-frequency beamed radio channel for transmitting information from point to point, and promises to become a valuable tool to electric power systems as a channel for the transmission of information. Relaying, telemetering, supervisory control, and communication are functions which could use such a channel. The information required by these functions now is being sent over pilot wires and power line carrier channels. The microwave channel, by virtue of its air-line transmission and the large number of quantities which can be transmitted from point to point on a single beam, opens up application possibilities which cannot be handled with present methods.

Microwaves are radio waves in the region from a few hundred megacycles up; these correspond to wave lengths from about 100 centimeters down. Radio waves of these short wave lengths travel generally in a straight line like light and cannot be picked up if intervening objects such as hills, buildings, or the curvature of the earth interfere.

Since the earth is spherical, a microwave beam that is ten miles from a point of tangency would be 66 feet above the earth's surface, and 264 feet above it when 20 miles away. Thus, it would be theoretically possible to go about 35 miles line-of-sight between two 200-foot towers. It may be necessary for the line of the microwave beam to clear the nearest obstruction by some 50 feet. If this 50-foot clearance is added, the tower height required for different transmission distances varies from 54 feet for a 5-mile channel to 462 feet for a 50-mile channel. Approximately half this distance can be covered with only one tower, and the other tower 50 feet high.

The number of microwave communicating channels which can be used is dependent on three factors:

1. Line-of-sight characteristic.
2. Angular directional characteristic.
3. Frequency selection.

Fifty miles away from a given installation, the line-of-sight of that installation would be 1,650 feet above the earth's surface and the same frequencies generally could be used over again. Thus the entire available spectrum may be thought of as being available in each 100-mile-square area. However, a great many channels could be used at the same frequency because of the directivity of the pattern. If a conservative figure of 20 degrees is taken, it is entirely possible that four signals could be sent in four directions from a given point without interfering.

There are several frequency bands which are available on an experimental license basis for power system applications using microwaves, some of which are for commercial use (power, gas, water, and steam utilities), some for government use, and some for joint use. These bands are located between 952 and 16,000 megacycles.

For example, consider the band from 952 to 960 megacycles, channels spaced 100 kc apart, and 80 such channels using the 8-megacycle band. Also, assume that six communication channels (voice channels) can be accommodated in each 100 kc of band width, or a combination of voice and about four audio tones, or about ten audio tones without voice. Using these figures, a single microwave channel can accommodate 6 voice and 24 tone channels, or a total of 60 tone channels without voice.

If four beam directions are assumed, then 1,920 voice channels or 19,200 audio tone channels easily could be made available in each 100-mile-square area. This can be compared very roughly with a saturation limit of the order of 30 voice channels or 300 tone channels available over power line carrier. In addition, the higher frequency microwave bands will accommodate more audio channels than the 952–960-megacycle band used in the foregoing example.

Advantages of the microwave system are

1. *Channel Reliability.* A microwave channel is reliable and is not dependent on the continuity of transmission line conductors or pilot wires, and is not subject to sleet, windstorm, or airplane damage.

2. *Facilities Per Channel.* The intelligence required by a large number of different functions can be transmitted on a single microwave channel using modulated subcarriers, as described.

3. *Freedom From Interference.* Interference in the microwave band is very small and even may be a negligible factor.

4. *Maintenance.* Since the microwave channel is independent of the power system, maintenance can be performed without the necessity of having any part of the power system out of service.

Disadvantages of the microwave system are

1. *Line-of-Sight.* The necessity of line-of-sight will have a number of disadvantages; in some cases, it will necessitate repeater stations and the reliability of power supply at this repeater must be assured.

2. *Power Supply.* The high-voltage requirement necessitates the use of an a-c power supply.

3. *Structure Rigidity.* There may be a problem of directivity caused by deflection of the antennas or mounting structures.

It is quite apparent from the economic and engineering possibilities of this system and from the general interest in it throughout the United States that this field definitely will develop. It will occupy part of the place now occupied by carrier, but probably never will displace carrier completely, and will provide power companies with an increased opportunity to control their own communicating facilities for important dispatching services and control functions.

Digest of paper **49-5**, "Microwave Channels for Power System Applications," recommended by the AIEE carrier current committee and approved by the AIEE technical program committee for presentation at the AIEE winter general meeting, New York, N. Y., January 31–February 4, 1949. Scheduled for publication in AIEE *TRANSACTIONS*, volume 68, 1949.

This digest of a report of the AIEE carrier current committee was prepared by **S. C. Leyland**, Westinghouse Electric Corporation, Newark, N. J.

Electrical Essay

Turn Ratio of Transformers

A CASE having two pairs of electrical terminals is said to contain a transformer. By steady-state 60-cycle measurements at the terminals, determine precisely the primary and secondary turn ratio. Assume that electrostatic capacity effects are negligible.

J. SLEPIAN (F '27)
(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

Answer to Previous Essays

Thevenin's Theorem. The following is the author's answer to his previously published essay (*EE, Apr '49, pp 307–08*).

The student should have short-circuited the rectifiers when taking measurements of the network impedance. The resultant resistance of 20 and 100 ohms in parallel is $16^2/_3$ ohms. The equivalent network is an electromotive force of 100 volts direct current (E_0) and a $16^2/_3$-ohm resistance (Z) in series with it. This equivalent network holds true only for an external circuit whose electromotive force, if any, does not exceed 120 volts direct current. For an external circuit with an electromotive force exceeding 120 volts direct current, the network is replaced by a 100-ohm resistance. For an external circuit with an electromotive force of negative polarity the equivalent network is 120 volts direct current and a 20-ohm resistance.

Presence of half-wave rectifiers in a circuit with variable electromotive forces introduces discontinuities in circuit constants depending on the directions and relative magnitudes of the electromotive forces. Thevenin's theorem must be applied with care within the limits of discontinuities. The essay was presented for the purpose of calling attention to this fact.

A. A. KRONEBERG (F '48)
(Southern California Edison Company, Los Angeles, Calif.)

Magnetic Speedometer for Aircraft. The following is the author's answer to his previously published essay (*EE, Apr '49, p 308*).

The invention is unsound.

When the airplane is at rest on the ground, the instrument described in the invention continues to give readings, because the rod is in the earth's electric field also. Using the language of the essay, the "electromotive force" arising from the electric field is $V=E_hl$ volts, where E_h is the horizontal component of the earth's electric field, in volts per centimeter. When in motion, the instrument presumably will read $V=10^{-8}Hlv+E_hl$. Since E_h is large and variable, the preceding equation is of little use to the pilot, for determining v.

The vertical electric gradient over the earth in fair weather is variable, but of the order of 100 volts per meter. Under a cloud, even without lightning it may be 10,000 volts per meter. Due to uneveness of the ground, and the location of the airplane relative to charged clouds, the horizontal component of the field, E_h, will have similarly large values. Hence the term in the equation for V, arising from E_h will be of the order of hundreds of volts, and will be very large compared to the term arising from H.

It might seem that some kind of shielding could be devised, which would screen the instrument from the earth's electric field, but still would permit the motion in the magnetic field to have its effect. To see that this is not the case, we must discourse on the relativity of the electromagnetic field. In this discourse we shall use centimeter-gram-second units, which should not affect its readability. E will be in electrostatic units, and H in electromagnetic units.

It must be noted that the electric and magnetic field have no absolute reality or significance, but are observed and defined only relative to some arbitrary frame chosen by the observer. The electric field usually is defined as the observed force per unit charge on a small charge at rest. But at rest relative to what? At rest relative to some arbitrary frame which the observer chooses to regard as at rest. If the observer changes his rest frame, that is, that system of material bodies which he chooses to regard as at rest, then the probe charge which he used before no longer serves to define the electric field. He must determine the force per unit charge now on another probe charge, one that is at rest relative to the new reference system, and therefore moving relative to the first probe charge. Now generally, the force per unit charge on the two probe charges both at a given point in space, but moving relatively to each other, will be different. Therefore, the observer will find two different values of the electric field, depending on whether he regards the one reference system or the other reference system as at rest.

The electric field component E_y is defined or observed by the equation

$$F_y=\rho E_y \tag{1}$$

in a reference co-ordinate system for which the probe coordinates (x,y,z) are unchanging, where F_y is the force component which must be applied to small probe of charge ρ to keep it at rest in the given co-ordinate system.

If a different reference rest system is used, we will need to use a different probe moving relatively to the first probe even if we retain the same charge ρ. We then will find a different F' and E', still connected by the same relation,

$$F_y'=\rho E_y' \tag{2}$$

This new E_y' is just as good in every way as the old E_y. There is no possible way of saying that one is right, and the other wrong. Each is the electric field relative to the reference frame in which its defining probe charge is at rest, and each serves to describe equally well the observed motions of charged bodies. The electric field exists and is known only relative to some arbitrarily chosen reference frame.

Similar remarks may be made about the magnetic field.

We may define it by the forces observed acting on moving probe charges. We find that we agree with experience, if we use the Lorentz formula:

$$F_y=\rho\left(E_y-\frac{1}{c}\ H_z v_x\right)=\rho\left(E_y-\frac{1}{c}H_z\frac{dx}{dt}\right) \tag{3}$$

where $v_x=\frac{dx}{dt}$ is the X component of velocity of the probe relative to the same reference frame which was used for defining E_y and c is a universal constant, the velocity of light. If a different reference frame is used, in which the probe charge has the co-ordinates x', y', z', then we may get a different H_z by the equation.

$$F_y'=\rho\left(E_y'-\frac{1}{c}H_z'v_x'\right)=\rho\left(E_y'-\frac{1}{c}H_z'\frac{dx'}{dt'}\right) \tag{4}$$

Suppose we know the components of E and H relative to one reference frame. Can we from these determine the components of E' and H' defined relative to another frame by the foregoing equations, if we know the motion of this second frame relative to the first frame? The answer is yes, provided we know how to calculate x', y', z', t', and F_y' from x, y, z, t, and F_y. For this last we need to know the kinematics and mechanics of the physical bodies we deal with; that is we need to know the properties of meter-sticks, clocks, and massive particles, as revealed by experience.

For relative velocities which are small compared to the velocity of light, as for example the velocity of our airplane relative to the earth, and the velocity of the particles of the rotating rod relative to the airplane, Newtonian space-time and Newtonian mechanics are well established as applicable. For reference frames in plane and earth respectively we have

$$x'=x-v_0t;\ y'=y;\ z'=z;\ t'=t;\ F_y'=F_y;\ m'=m;\ \rho'=\rho \tag{5}$$

where v_0 is the constant velocity of the airplane relative to the earth, and in the X direction, and provided the reference frame in the earth is a Galilean frame, that is, one in which Newton's laws of particle dynamics holds. This last is true for our purpose, since the effect of the earth's "rotation" may be taken into account by a change in the gravitational potential, and the Coriolis forces will have an effect only over long distances or long times, as in a Foucault pendulum experiment.

In any case, for relatively moving Galilean frames with uniform relative velocity v_0, and with v_0 and any other velocities considered, small compared to that of light, equation 5 holds.

These equations give for the transformation of the velocities, applicable to any particular particle, as for instance a moving probe charge,

$$v_x'=\frac{dx'}{dt'}=\frac{dx}{dt}-v_0=v_x-v_0;\ v_y'=v_y;\ v_z'=v_z \tag{6}$$

Then from the defining equations of the electric and magnetic fields, and the equality of F_y and F_y',

$$F_y'=\rho\left(E_y'-\frac{1}{c}H_z'v_x'\right)=\rho\left(E_y'-\frac{1}{c}H_z'[v_x-v_0]\right)=$$
$$\rho\left(\left[E_y'+\frac{1}{c}H_z'v_0\right]-\frac{1}{c}H_z'v_x\right) \tag{7}$$

$$F_y=\rho\left(E_y-\frac{1}{c}H_zv_x\right)$$

we get

$$E_y'=E_y-\frac{1}{c}\ H_zv_0 \qquad H_z'=H_z \tag{8}$$

The observer on the airplane makes experiments with charges, at rest or in motion relative to the airplane, and is able to account for what he observes by introducing electric and magnetic fields. If he likes, he may regard his airplane as at rest, and relative to axes fixed in the airplane, his experiments will reveal E' and H'. This is all his experiments can do.

On the other hand, he may prefer to use axes fixed on the earth, and relative to these axes, if he knows the value of v_0 he may determine E and H, which should agree with the electric and magnetic fields found by an observer on the earth. E, H, and E', H' are related by equations 8 and it is only through this relation that v_0 may be determined.

It should be clear now that for the observer on the airplane to determine the relative velocity of the earth from electrical experiments made only on the airplane, he must know not only H_z, but also E_y in equations 8. Since E_y referred to the earth is large and variable, the proposed speedometer for aircraft cannot be made operative.

When the velocities under consideration are not small compared to that of light, the velocities determined by meter-sticks and clocks no longer satisfy equations 6. However, we may make a modification in equations 5 changing them to the Lorentz transformation of the restricted theory of relativity, and then we obtain a modified set of equations 6 which do not disagree with the Michelson-Morley experiment on the velocity of light relative to relatively moving frames.

The Lorentz transformation replacing equation 5 does not leave the equations of Newtonian mechanics invariant. We therefore modify Newtonian particle mechanics to relativistic particle mechanics. We are then able to use those equations of equation 7 which involve only the first equality signs on each line, and arrive at transformation equations for the electric and magnetic field which are valid also for v_0 not small compared to c, the velocity of light. We get

$$E_y'=\frac{E_y-\frac{1}{c}\ H_zv_0}{\sqrt{1-\frac{v_0^2}{c^2}}} \qquad H_z'=\frac{H_z-\frac{1}{c}\ E_yv_0}{\sqrt{1-\frac{v_0^2}{c^2}}} \tag{9}$$

For the airplane and earth, these equations reduce to the equations 8 since $\frac{v_0^2}{c^2}$ is negligible compared to 1, and $\frac{1}{c}E_yv_0$ is negligible compared to H_z north of latitude 15 degrees north.

J. SLEPIAN (F '27)
(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

INSTITUTE ACTIVITIES

The Electrical Engineer in Civic Affairs

—*A Message From the President*

On outstanding occasions in our Institute life we have been carried to pinnacles of inspiration and vision for future achievement. So were we at our recent winter general meeting in New York, N. Y., when Charles E. Wilson addressed some 1,000 of our members on "The Professional Estate." Full text of Mr. Wilson's address was published in *ELECTRICAL ENGINEERING* (*EE, Mar '49, pp 187–90*). I trust you all have read it, thought about it, and have brought it into your lives as motivation for the unparalleled opportunities of the electrical engineer to serve with his fellowmen.

Particularly do I quote from one part of Mr. Wilson's address:

> His (Emerson's) final point was this—that it was the duty of thinking men, and particularly of the scholar, as the foremost professional man of his age, to leave off being a mere bookworm and lead the way back to a balanced and integrated society. If it is true, as I think, that the engineer-scientist is the foremost professional man of this age, then do you here not also have the obligation and the duty, as individuals and as an association, to give some thought to playing a similar role for the age which you have created?
>
> This may seem to be rather abstruse talk, in marked contrast to the kinds of things that you are here considering in papers and discussions. It is one of those strange quirks of human nature that most men are not at all embarrassed or reluctant to discuss with their fellows the day-to-day technical and professional problems on which they are engaged, but the more their minds run to shop talk on any plane, the more tongue-tied and thought-tied they become when a general question of morals or human behavior is posed. And yet these are very simple matters. The American Medical Association, the Society for the Advancement of Science, or the AIEE do not and cannot operate in the rare atmosphere of science and technology alone. Once they could, perhaps, but not today. Their members are not machines but men. By banding together they have become greater, and the sum is more significant than the parts. By your association you have increased your professional stature and taken upon yourself, perhaps unconsciously, the duty to support and strengthen the society of which you are a part. You are bound henceforth not only to understand the technological progress which you are achieving in your specific ways, but you must understand the kind of society which supports that progress and in turn is borne forward on its shoulders.

As I have been privileged to address our Institute Sections and Student Branches this year, I have tried to bring to you this very concept. From everywhere I have had approval. But beyond the approval I trust that from everywhere there will come into definite action the conscious progression by our members in our general, District, Section, and Student Branch meetings the presentation for discussion of their living with their fellowmen beyond the technical along the avenue of the second mile of life.

It seems to me this well can follow the pattern of our technical presentations and discussions to make them completely educational and inspirational for great good. In our technical work the engineer accomplishes a technical result. He describes it and presents it in meeting assembled. There is discussion of his accomplishment. Upon approval it is included in our *TRANSACTIONS* for permanent record. Everyone in our Institute and beyond is served.

Cannot the same apply to a general service by one of our members? Perhaps our member has rendered a service to the local schools; perhaps our member has

Everett S. Lee

studied the tax structure of his community with a resulting useful progression; perhaps our member has been instrumental with others in bringing into being an advance in government reorganization; perhaps our member has worked out a plan for some phase of national security which has advantages; perhaps our member has had an experience in management relations application which has been for great good which he could well describe; perhaps our member has been through some local community experience to provide an advance which could well be the subject of a presentation to advantage under an appropriate title. The requirements for an effective presentation are: first, that some useful result has been accomplished by the member or by a group; second, that it has general application to be useful to others; third, that it represents an advance.

I know from experience that many of our members have progressed accomplishments beyond the technical which have been of value to their fellowmen. That they do not describe them for presentation is due largely to their inherent modesty. They are so used to a life of engineering service that any other service they render is to them a service which they do not like to shout about from the housetops. I believe this is the basis for their being "the more tongue-tied and thought-tied they become when a question of morals or human behavior is posed," of which Mr. Wilson speaks. And yet if you get together a gang of engineers in the back room, the sky is the limit to their tongue movements and for their thought processes; their scope knows no boundaries, their solutions no end.

And so for those of our members who have done these things of worthwhile accomplishment, I urge that you make the accomplishment of greater value in extent by describing it for presentation so others may have knowledge of it to realize its advantages; and by so doing the greater satisfaction also will come to you in the service rendered. Would our members do this, I am sure our program chairmen would be receptive to a placement of such on our programs and our membership would give of their time to the hearing, to the reading, to the study, to the discussion, to the further progression. These, as I see it, are the basic details of progression; the result will be for enlargement into great good in proportion to the service rendered and in proportion to the extent of application. These are the same basic fundamentals underlying technical advance.

As I read Mr. Wilson's address, I see in it the independence of the engineer that the world needs him for engineering and that the world needs the electrical engineer for electrical engineering. This is his great responsibility in life. It is in the doing of it substantially and superlatively that progress results. It is in the telling of it that progress is augmented to his fellowmen. This is his independence.

Then there is the dependence of the engineer upon his fellowmen and of the electrical engineer upon his fellowmen. In this dependence his life extends beyond the technical into everyday relations. Here again it is in the doing of it substantially and superlatively that progress is augmented to his fellowmen. This is his dependence.

May each of our members recognize their responsibilities of independence and of dependence. And may these be made more clearly evident and understood. Our Institute gives this opportunity to those of our members who will use it. May their number increase.

Official United States Navy photo

Of interest to members attending the summer general meeting in Swampscott, Mass., will be the historic United States Frigate "Constitution," popularly known as "Old Ironsides," which is now permanently moored at the United States Naval Shipyard in nearby Boston. The ship is open to visitors every day between 10:00 a.m. and 4:00 p.m.

Program Announced for Materials Handling Conference

The program has been announced for the forthcoming AIEE conference on electric equipment for materials handling bridges, to be held at 10 a.m., Friday, May 13, 1949, in the Empire Room of the Hotel Cleveland, Cleveland, Ohio. The conference will be sponsored jointly by the Cleveland Section of the AIEE and the AIEE subcommittee on materials handling.

The following papers will be presented:

Electrical Design Practices on D-C Material Handling Bridges. *E. M. Hays*, Dravo Corporation, Pittsburgh, Pa.

Adjustable Voltage Drives for Ore Bridges and Unloaders. *M. A. de Ferranti*, General Electric Company, Schenectady, N. Y.

Presentation of prepared discussions of foregoing papers.

Open forum—Representatives of the bridge builders, equipment manufacturers, and users have been asked to form a panel to discuss and answer questions raised by the conference group on electric installations for bridges.

Registration fee for the meeting, which is open to members of the AIEE and others, is $3 and includes luncheon. For advance registration contact A. H. Myles, Electric Controller and Manufacturing Company, 2700 East 79 Street, Cleveland 4, Ohio.

Second Textile Conference Scheduled to Meet in Atlanta

A joint meeting of the textile subcommittee of the AIEE committee on general industry applications and the AIEE Student Branch of the Georgia Institute of Technology will be held in Atlanta, Ga., on May 26 and 27, 1949. This is the second AIEE textile conference; the first was held jointly with the Boston Section in Cambridge Mass., on May 3. No registration fee will be charged for the conference, and no special publication of the proceedings in booklet form is planned.

The program for the first day of the conference will include the following scheduled papers:

Electronic Instrumentation as Applied to the Textile Industry. *Lee Chuckler*, Minneapolis-Honeywell Company, Philadelphia, Pa. (this paper also was presented at the May 3 conference)

Use of Strain Gauges in Loom Studies. *Victor Sepavich*, Crompton and Knowles Loom Works, Worcester, Mass.

Selecting Electric Equipment for Textile Machines. *F. D. Snyder*, Westinghouse Electric Corporation, Boston, Mass.

The second day's program will include:

Selection of Electric Drive for Looms. *R. J. Demartini, A. F. Lukens*, General Electric Company, Schenectady, N. Y.

Minimum Fire Hazards in Electric Equipment in the Textile Industry. *C. F. Hedlund*, Associated Factory Mutual Fire Insurance Company, Boston, Mass.

Electrostatic Air Cleaning in the Textile Industry. *Robert Posey, C. H. McWhirter*, Westinghouse Electric Corporation, Atlanta, Ga.

Also, a paper prepared by the Georgia Institute of Technology, the subject of which has not been announced as yet.

The following is the personnel of the textile subcommittee:

F. D. Snyder, *chairman*, S. A. Bobe, D. McConnell, A. P. Lewis, H. C. Uhl, L. T. Jester, A. W. Frankenfield, H. Haley, R. S. Stribling, R. J. Demartini, V. Sepavich, R. B. Flowers, A. F. Lukens, A. T. Bacheler

Future AIEE Meetings

AIEE Conference on the Textile Industry
Massachusetts Institute of Technology, Cambridge, Mass.
May 3, 1949

AIEE Conference on Electric Equipment for Materials Handling Bridges
Hotel Cleveland, Cleveland, Ohio
May 13, 1949

AIEE Conference on the Textile Industry
Georgia School of Technology, Atlanta, Ga.
May 26–27, 1949

Summer General Meeting
New Ocean House, Swampscott, Mass.
June 20–24, 1949
(*Final date for submitting papers—closed*)

Pacific General Meeting
Fairmont Hotel, San Francisco, Calif.
August 23–26, 1949
(*Final date for submitting papers—May 25*)

Midwest General Meeting
Netherland Plaza Hotel, Cincinnati, Ohio
October 17–21, 1949
(*Final date for submitting papers—July 19*)

Winter General Meeting
New York, N. Y.
January 30–February 3, 1950
(*Final date for submitting papers—November 1*)

Summer Meeting Program to Include Five Conferences

A technical program including 22 sessions, 5 technical conferences, and a general session will be a feature of the 1949 AIEE summer general meeting in Swampscott, Mass., according to plans recently announced. The meeting will take place June 20–24, with headquarters at the New Ocean House.

During this year's summer meeting, the annual meeting of the Institute will be held, Wednesday morning, June 22, at which time the Lamme Medal will be presented to V. K. Zworykin of the Radio Corporation of America Laboratories Division, Princeton, N. J. A biographical sketch of the medalist appeared in the April issue (*EE, Apr '49, pp 361–2*). The report of the committee of tellers on the ballot cast for the election of officers also will be presented at this time.

Trips to interesting places along the north shore of Massachusetts are being planned, and the bathing and sports facilities of the hotel, which are considered excellent, will be at the disposal of Institute members. Special attention is being given to arrangements for the entertainment of women guests.

Special convention rates at the New Ocean House, including rooms and meals, are listed below. These rates are daily per person.

Double room with bath, twin beds	$9.50 and	$10.00
Double room with bath, twin beds, ocean front		10.50
Large room with bath, three beds	8.75 and	9.00
Large room with bath, four beds	8.50 and	8.75
Double room with running water, twin beds	8.75 and	9.00
Suite, two double rooms, bath between, four beds	9.00 and	9.50
Suite, two double rooms, bath between, six beds	8.50 and	8.75
Choice corner or bay window room with bath, twin beds	11.00 and	12.00
Single room with bath	12.00 and	13.00

For those planning to drive to the meeting,

Shell road maps and complete touring information may be obtained through local Shell service stations or by writing directly to the Shell Touring Service, 50 West 50 Street, New York, N. Y.

Members of the summer general meeting committee are

E. W. Davis, *general chairman;* M. A. Princi, *vice-chairman;* R. E. Muehlig, *secretary-treasurer;* R. G. Porter; F. P. Taugher; R. G. Slauer

Subcommittee chairmen are

A. Lee O'Banion, *registration;* R. G. Conners, *hotels;* J. O'R. Coleman, *meetings and papers;* H. B. McIntyre, *publicity;* J. M. Whittenton, *inspection;* F. S. Bacon, Jr., *hospitality;* G. J. Crowdes, *smoker and banquet;* C. A. Corney, *finance;* Mrs. Fred Hauessler, *ladies committee;* A. B. Whitehouse, *transportation;* E. W. Boehne, *Student activities*

San Francisco Selected as Site for Pacific General Meeting

The AIEE Pacific general meeting for 1949 will be held in San Francisco, Calif., at the Fairmont Hotel from Tuesday, August 23, to Friday, August 26. Tentative arrangements have been completed and a condensed schedule of events is given in the following. The year 1949 is a commemorative one for San Francisco, marking, as it does, the centennial of the great California gold rush. Anyone planning a western vacation this Fall will find many events of interest in that historic city and, by combining vacation with attendance at the Pacific meeting, can make a stay in San Francisco a highly profitable one.

TECHNICAL PROGRAM

There will be technical sessions on each meeting day, with subjects of interest to all included in the program. Registration will begin on Tuesday morning, August 23, to be followed by the opening meeting and a general session. The remainder of the technical meetings are scheduled tentatively as follows:

Tuesday, August 23 (afternoon)
- Power generation and distribution meetings
- Air transportation meetings

Wednesday, August 24
- Home heating symposium
- Air transportation meetings
- Power generation and distribution meeting

Thursday, August 25
- Industrial meetings
- Air transportation meeting

Friday, August 26
- Student sessions
- Power generation and distribution
- Electronics and communication meetings
- Air transportation conference

INSPECTION TRIPS

The San Francisco area has many points of interest that are to be included on inspection trip itineraries. Those selected include:

The new Station *P* of the Pacific Gas and Electric Company

Radiation Laboratory of the University of California

San Francisco Naval Shipyard at Hunters Point

Columbia Steel Company at Pittsburg, Calif.

Ames Laboratory (NACA) Moffett Field

ENTERTAINMENT

An especially carefully selected program of entertainment is planned. The committee has given full consideration to the fact that those attending the meetings may wish to partake individually of the many entertainment possibilities that San Francisco offers.

The planned program will open with a general luncheon at noon on the first day. During the afternoon there will be an informal tea for the women, and on Wednesday, August 24, they will go on a conducted trip to Palo Alto and will visit Stanford University. Lunch will be served at the Allied Arts.

On Thursday, the women will be taken on a tour through San Francisco's famous Chinatown. There will be luncheon at the Cathay House, a visit to Fisherman's Wharf, and a boat excursion on San Francisco Bay. On Thursday evening an informal banquet will be held. Friday, August 26, will be left free for those who wish to shop or visit.

SPORTS

The annual golf tournament will be held on Thursday afternoon. For those who enjoy tennis, there will be facilities at the California Tennis Club.

Information concerning hotel reservations advance registration for the meeting, details of the technical papers, and other data will be published in forthcoming issues of *ELECTRICAL ENGINEERING.*

Meeting Held by Committee on Standards Co-ordinating

The AIEE Standards co-ordinating committee number 8 (insulation co-ordination) met in Pittsburgh, Pa., on January 20, 1949. According to a report by the chairman of the committee, J. H. Foote of the Commonwealth and Southern Corporation, Jackson, Mich., the following actions were taken at this meeting.

BASIC INSULATION LEVEL PRINCIPLES ADOPTED BY THE COMMITTEE

The committee had agreed at its previous meeting (May 1948) to consider basic insulation levels on the basis of three operating voltage ranges: distribution range, subtransmission range, and transmission range. It was decided to limit consideration in this particular meeting to the transmission range, or about 450-kv basic insulation level and above, and the following seven basic principles were adopted for guidance of the com-

Annual Meeting

The annual meeting of the American Institute of Electrical Engineers will be held in Swampscott, Mass., at 10:00 a.m., Wednesday, June 22, 1949, during the summer general meeting.

At this meeting the annual report of the board of directors and the reports of the committee of tellers on the ballot cast for the election of officers will be presented. The Lamme Medal will be presented to V. K. Zworykin (M '22, F '45).

Such other business, if any, as properly may come before the annual meeting may be considered.

Signed H. H. HENLINE
Secretary

Union Pacific Railroad photo

Quaint cable cars climb the hills of San Francisco, where the Pacific general meeting will be held

mittee in its studies relating to basic insulation levels:

1. Basic insulation levels shall be designated in terms of the crest value of a $1^1/_2\times40$ microsecond impulse voltage test wave as has been customary in the past.

2. The general principle of insulation co-ordination requires the recognition of the necessity for the postulation of a suitable margin between the voltage level that is assumed to be held by a suitable protective device and an associated basic insulation level.

3. Each value of basic insulation level should be chosen so that it should apply suitably to effectively grounded systems and also, if practicable, apply to ineffectively stabilized systems, although the systems would not operate ordinarily at the same line-to-line voltage.

4. The basic insulation level tabulation to be developed by this committee should recognize the differences in insulation level requirements for solidly and effectively grounded systems and for those with ineffectively stabilized neutrals.

5. The techniques used in tests for determining conformance of apparatus to requirements of basic insulation levels should be under the cognizance of the appropriate AIEE committees.

6. Equipment represented as conforming to basic insulation level requirements should be capable of demonstrating such conformance by suitable tests.

7. The user should be judge in the selection and application of basic insulation levels to his systems.

During the meeting there was much discussion relating to the higher basic insulation levels. A preliminary list of proposed basic insulation levels prepared from suggestions by various members was the basis for the discussions and the following four points of agreement summarize the results:

1. There is a feeling that it might be well to re-examine the list of suggested basic insulation levels with particular reference to their application on solidly and effectively grounded systems.

2. There possibly should be a variable approach to the margin applied in selecting a basic insulation level, and components of the margin required should be examined.

3. The performance of lightning arresters at higher kilovolt ratings should be explored for possible lowering of basic insulation levels by lowering the protected levels.

4. Half steps may be required in the basic insulation level tabulation to accommodate the insulation requirements of equipment both near and distant as related to the protective devices.

Also announced at this meeting was the resignation of A. C. Monteith from the committee and the appointment of C. F. Wagner to serve as member in his place. F. L. Snyder was appointed as alternate member to fill the vacancy created.

AIEE Board of Directors Holds Regular Meeting in New York

A regular meeting of the AIEE board of directors was held at Institute headquarters, New York, N. Y., on February 3, 1949.

President Lee mentioned visits which he had made to Sections and Student Branches, and Vice-Presidents Callahan and Pingree gave brief reports of occasions at which they had represented the Institute.

Minutes of the meeting of the board of directors held October 19, 1948, were approved.

MEMBERSHIP ACTIONS

Actions of the executive committee on applications were reported and confirmed, as follows. As of November 26, 1948: 3 applicants elected to grade of Fellow; 4 applicants transferred and 34 elected to the grade of Member; 102 applicants elected to the grade of Associate; 3,172 Student Members enrolled. As of December 27, 1948: 27 applicants transferred to the grade of Fellow; 79 applicants transferred and 14 elected to the grade of Member; 110 applicants elected to the grade of Associate; 1,624 Student Members enrolled.

Recommendations on applications for admission, transfer, and Student Membership adopted by the board of examiners at meetings held October 21, November 18, and December 16, 1948, and January 20, 1949, were reported and approved. The following actions were taken upon recommendation of the board of examiners: 1 applicant was transferred to the grade of Fellow; 26 applicants were transferred and 36 were elected to the grade of Member; 156 applicants were elected to the grade of Associate; 609 Student Members were enrolled.

FINANCES

A comparative statement of income and expenses for the first four months of the present budget year (beginning October 1) and of the same period last year was shown, indicating a slight increase this year in both income and expenditures, with the rate of increase in expenditures this year over last year slightly higher than the rate of increase in income.

Monthly expenditures were reported by the chairman of the finance committee and confirmed by the board of directors as follows: November 1948, \$76,137.90; December 1948, \$57,321.52; January 1949, \$62,000.59.

The directors adopted a resolution dropping from membership any persons owing dues for the fiscal year which began May 1, 1947, with the understanding that such member may become reinstated without the formality of an application for reinstatement if dues in arrears are paid prior to May 1, 1949.

Continuing the provision in force for the past several years, the directors authorized the acceptance, during the fiscal year beginning May 1, 1949, of payments of membership dues on the basis of the par currency value of countries affected by abnormal exchange rates—the member concerned to be granted an exchange allowance corresponding to the difference between the New York exchange value and the normal par of his currency, such allowance not to exceed 40 per cent of the dues payable, and not to apply to purchases of or subscriptions to Institute publications; a corresponding reduction in appropriation payments to be applicable to Institute Sections in any countries affected under the foregoing provision.

The usual travel allowance was authorized for a joint conference on Student activities of Districts 8 and 9 and the Student Branches at the University of British Columbia and the University of Alberta, in San Francisco, Calif., during the 1949 Pacific general meeting.

APPOINTMENTS AND OTHER ACTIONS

The board of directors confirmed the action of AIEE representatives on the Engineers Joint Council in voting to rescind the bylaws of that body, and approved a constitution for EJC, which went into effect January 1, 1949.

Representatives of AIEE on the Engineers Joint Council under the new constitution were announced as follows:

Under article II, section 1(a)—J. Elmer Housley, past president AIEE; Blake D. Hull, past president AIEE; H. H. Henline, secretary AIEE

Under article II, section 1(b)—Everett S. Lee, president AIEE

Under article II, section 1(c)—J. F. Fairman, director AIEE, official alternate

The appointment by the president of the following AIEE representatives on EJC committees was confirmed:

EJC Labor Legislation Panel—E. H. Bancker

EJC Committee on Collective Bargaining—O. W. Eshbach

The following meetings were authorized:

Southern District meeting, in the Spring of 1951, at a location to be decided later.

Midwest general meeting, Cleveland, Ohio, during the week of October 22, 1951. (Note: Subsequent developments indicate a change in date to October 29–November 2.)

Upon petition of the members and Sections concerned and recommendation of the Sections committee, the following actions were taken:

The organization of a Miami Section was authorized, with territory consisting of the Florida counties of Okeechobee, St. Lucie, Glades, Martin, Henry, Palm Beach, Collier, Broward, Dade, and Monroe.

Transferred to the West Virginia Section the following counties: Boyd, Greenup, and Lawrence Counties in Kentucky—from Louisville Section; Scioto County in Ohio—from Cincinnati Section; Gallia and Lawrence Counties in Ohio—from Columbus Section.

Changed the name of the new Section at Niagara Falls to "Niagara International Section," its territory, already assigned, to be included in District 10 (Canada).

Upon recommendation of the committee on Student Branches, the establishment of Student Branches at Fenn College, Cleveland, Ohio, and Louisiana Polytechnic Institute, Ruston, Ala., was authorized.

In accordance with section 25 of the bylaws, the board of directors adopted a resolution determining the date and location of the 1949 annual business meeting of the Institute, namely, June 22, 1949, at Swampscott, Mass.

In accordance with section 83 of the bylaws, the Standards committee reported the following appointments of representatives and approval of Standards:

R. E. Poole as a member of the AIEE delegation on American Standards Associations ectional committee *C16* "Radio."

E. I. Green as chairman of the AIEE delegation on sectional committee *C42* "Definitions of Electrical Terms," the delegation consisting of E. I. Green, *chairman*, J. E. Clem, C. L. Dawes, G. H. Garcelon E. B. Paxton, F. B. Silsbee, and C. F. Wagner.

Reorganization of AIEE delegation on sectional committee *C50* to consist of R. Rudenberg, *chairman*, P. L. Alger, C. L. Killgore, S. H. Mortensen, V. E. Schlossberg, W. I. Slichter, *representatives*, and J. E. Clem, *alternate*.

D. E. Renshaw and A. C. Muir, representative and alternate respectively, on sectional committee *M2* "Safety Rules for Installing and Using Electric Equipment in Coal Mines."

L. G. Pacent as AIEE representative on sectional com-

mittee Z24 "Acoustical Measurements and Terminology."

A. B. Campbell as an AIEE alternate on sectional committee C2 "National Electrical Safety Code."

L. E. Fogg as the AIEE representative on American Society for Testing Materials committee B1 "Copper and Copper Alloyed Wire for Electric Conductors."

Approval of AIEE Standard 45 "Recommended Practice for Electric Installations on Shipboard," December 1948 edition.

The directors confirmed the action of the Standards committee in approving, by a vote of 22 to one, a revision of AIEE Standards 601 and 602 "Preferred Standards and Standard Specification Data for Generators, for Large 3,600-Rpm 3-Phase 60-Cycle Condensing Steam Turbine-Generators."

The president was authorized to appoint a representative to attend the Pan-American Engineering Congress, Rio de Janeiro, Brazil, July 15–24, 1949.

Vice-President G. W. Bower and A. P. Godsho, chairman of the Philadelphia Section, were appointed delegates to the annual meeting of the American Academy of Political and Social Sciences to be held in Philadelphia, Pa., April 8–9, 1949.

Secretary H. H. Henline was appointed as AIEE delegate to the Conference of Representatives From Engineering Societies of Western Europe and the United States to be held in London, England, in September 1949.

Upon recommendation of the AIEE committee on safety, the board of directors approved a proposal for joint sponsorship with the Edison Electric Institute of a program proposed by the accident prevention committee of EEI for research on resuscitation from electric shock, at Johns Hopkins University.

The directors authorized the president to appoint a representative on the Hoover Medal Board of Award for the 6-year term beginning in 1949 to succeed Doctor John C. Parker (David C. Prince subsequently was appointed), two representatives on the council of the American Association for the Advancement of Science for the term of two years ending December 31, 1950 (J. W. Barker and I. Melville Stein were reappointed), and a representative to fill the unexpired term of Reginald L. Jones, deceased, on the Standards Council of the American Standards Association.

Upon recommendation of the committee on constitution and bylaws, the board of directors adopted a new bylaw, to be inserted between sections 73 and 74, as follows:

Section 73A. The Members-for-Life fund committee shall consist of not less than five members, one of whom shall be a member of the board of directors. The committee shall make recommendations to the board (of directors) for the accumulation and disbursement of the Members-for-Life fund. The fund represents continued payments of dues by Members-for-Life after the date at which they qualify for exemption of dues (in accordance with bylaw section 19), together with the returns from investment of unexpended fund principal.

Also, as recommended by the committee, section 31 of the bylaws was amended by the addition of the following as the last sentence of the section:

A chairman or a secretary of any Section in the District may, in his absence, be represented (with written approval of the vice-president) at the District executive committee meeting by an alternate, who shall have full voting power.

It was decided to hold the next meeting of the board of directors in Dallas, Tex., on Wednesday, April 20, during the AIEE South West District meeting.

Other matters were discussed, without final action.

ATTENDANCE

Present at the meeting were

President—Everett S. Lee, Schenectady, N. Y.

Past President—J. Elmer Housley, Alcoa, Tenn.

Vice-Presidents—J. H. Berry, Norfolk, Va.; G. W. Bower Haddonfield, N. J.; J. L. Callahan, New York, N. Y.; D. I. Cone, San Francisco, Calif.; I. M. Ellestadt, Omaha, Nebr.; D. G. Geiger, Toronto, Ontario, Canada; Richard McKay, Spokane, Wash.; G. N. Lingree, Dallas, Tex.; E. W. Seeger, Milwaukee, Wis.; Victor Siegfried, Worcester, Mass.

Directors—W. L. Everitt, Urbana, Ill.; J. F. Fairman, New York, N. Y.; C. W. Fick, Cleveland, Ohio; J. M. Flanigen, Atlanta, Ga.; R. T. Henry, Buffalo, N. Y.; M. D. Hooven, Newark, N. J.; F. O. McMillan, Corvallis, Oreg.; A. C. Monteith, East Pittsburgh, Pa.; J. R. North, Jackson, Mich.; Elgin B. Robertson, Dallas, Tex.; Walter C. Smith, Palo Alto, Calif.; E. P. Yerkes, Philadelphia, Pa.

Treasurer—W. I. Slichter, New York, N. Y.

Secretary—H. H. Henline, New York, N. Y.

COMMITTEE NOTES •

Editor's Note: This department is being created for the convenience of the various AIEE technical committees. It will include brief news reports of committee activities and proposed plans for such projects as special technical conferences and sessions at general meetings. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

General Applications Group

Committee on Production and Application of Light. (*Harris Reinhardt, chairman; Frank Hansen, vice-chairman; C. C. Whipple, secretary.*) The AIEE committee on production and application of light believes that the subject of lighting is of sufficient general interest to justify at least one meeting per year in each of the AIEE Sections. To encourage such meetings, a letter has been sent to each Section offering the assistance of the committee in arranging a program of this nature.

One of the most active subcommittees in this group is the subcommittee on nomenclature of electric discharge lamps which has been working with the electronics committee in preparing definitions of electric discharge lamps. This subcommittee, under the chairmanship of E. H. Salter, has completed a report which was approved by the committee at a meeting held during the 1949 winter general meeting.

Because of the increasing interest in infrared and ultraviolet radiations and their applications, a subcommittee has been organized in each of these fields. The subcommittee on infrared radiation, under the chairmanship of E. A. Linsday, is working in co-operation with two other AIEE infrared subcommittees: radiant heating subcommittee under the electric heating committee; infrared applications subcommittee under the electronics committee. The subcommittee will encourage the use of electric infrared radiation for those processes for which it is suitable by the collection and dissemination of available data, as well as the encouragement of new research. Investigations are being carried on at the present time on infrared sources, techniques, and measuring instruments. A program is also under way for the collection of fundamental application data.

The subcommittee on ultraviolet radiation, under the chairmanship of A. J. Dusault, is working on a paper which will give general background material on ultraviolet radiations.

Committee on Domestic and Commercial Applications. (*M. M. Brandon, chairman; Carl F. Scott, vice-chairman; Wesley Weinerth, secretary.*) The AIEE committee on domestic and commercial applications long has been aware of the feeling on the part of many Institute members that engineers in general were not cognizant of the fine engineering done in the appliance field and, as a consequence, were not as inclined to take as active a part in programs relating to appliance engineering as the size and importance of this field warranted.

Carl F. Scott, vice-chairman of the committee, in a paper presented at a symposium at the 1949 winter general meeting and subsequently published in *ELECTRICAL ENGINEERING* (*EE, Mar '49, pp 205–11*), pointed out some of the very involved engineering necessary in the design of appliances. A symposium on electric house heating also is being planned by this committee for the Pacific general meeting in San Francisco in August, because of the great interest on the West Coast in electric heating, and an effort is being made to interest local Sections in having sessions on the subject of appliance engineering so as to provide a forum for the large number of engineers now engaged in this field and having no particular interest in power apparatus or the many other fields of electrical engineering.

It is hoped also that this committee, in conjunction with some of the other committees of the Institute, can prepare a series of papers on appliances from the point of view of the utility, of the customer, and of the appliance manufacturer. Apparently little effort has been devoted in the past to such comprehensive consideration, although the ultimate user certainly is interested in what all of this engineering activity means to him. If appliance engineers are interested in taking part in this activity, they would be welcome as members of this committee.

Communication and Science Group

Communication Committee. (*Rothwell E. Smith, chairman; H. I. Romnes, vice-chairman; F. B. Bramhall, secretary.*) Some of the most intriguing and complex examples of "mechanized thinking" are found in telephone switching circuits. A vague appreciation of this fact comes to any engineer who considers that in New York City, for example, seven short pulls of the telephone dial automatically will set up a connection in a few seconds between any pair of more than two million telephones. What happens during those few seconds is that a private voice highway is established out of available sections that can be linked together

Fenn College Forms Engineering Council

With the recent approval of its engineering school by the Engineers Council for Professional Development and its subsequent acceptance into several national professional engineering societies, Fenn College, Cleveland, Ohio, announces the formation of an engineering council, to meet at the beginning of each school quarter. The purpose of the council, which is composed of the chairman and vice-chairman of the local group of each organization (AIEE, Institute of Radio Engineers, American Society of Mechanical Engineers, Society of Automotive Engineers, American Institute of Chemical Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Civil Engineers), is to unite the separate societies for purposes of advertising, education, and fellowship. Shown here is the registration booth used for the successful membership drive which was held during quarterly registration, February 28 and March 1. The booth will be used again during future quarterly registrations

in more than 2,000 billion possible combinations.

The circuits that accomplish this feat are primarily relay circuits. Relatively little information has been published on such circuits, in spite of the fact that our daily living—business and social—has come to depend on them so completely. The communication committee, therefore, is sponsoring a symposium of five papers on fundamental and functional relay switching circuit design for the AIEE summer general meeting in Swampscott, Mass. Certain of these papers will cover philosophical aspects of relay circuits, such as the rigorous logic embodied in them, the precision of statements represented by them, the influence of existing and preceding events on their actions. The other papers will present examples of applications of relay circuit design technique to accomplish specific functions, such as selecting, counting, information coding or decoding.

Instruments and Measurements Committee. (*E. I. Green, chairman; W. R. Clark, vice-chairman; M. B. Stout, secretary.*) The AIEE instruments and measurements committee held its Spring meeting in Washington, D. C., at the National Bureau of Standards on March 30, 1949. Doctor F. B. Silsbee acted as host for the meeting and H. Lyons, J. G. Reid, Jr., and others assisted in the arrangements. Following the meeting there was an inspection trip through some of the laboratories of the bureau including those concerned with establishment and maintenance of fundamental units, high-frequency and microwave standards, high-voltage measurements, and development of electron tubes and electronic engineering. On the following day a number of committee members visited the newly built Naval Ordnance Laboratory at White Oak, Md.

Industry Group

Committee on General Industry Applications.* (*L. A. Umansky, chairman; Kennard Pinder, vice-chairman; J. C. Fink, secretary.*) This committee was organized in the Summer of 1947. It has directed its main effort toward organizing, under AIEE auspices, electrical engineers in each of the several industries which either were not covered by any other engineering society, or—when such society existed—electrical engineering problems were not covered in its activities.

For this purpose the committee has set up the following subcommittees: rubber and plastics industries; pulp and paper industry; textile industry; machine tool industry; materials handling industry. Electrical engineers prominent in these industries were invited to join these subcommittees. Technical sessions or conferences were organized, devoted exclusively to electrical matters pertaining to these individual industries. For instance, a conference on rubber was held at Akron, Ohio, on April 20, 1948; another one, again at Akron, was held on April 26, 1949. This, undoubtedly, will become a regular annual affair. The textile group held a 1-day session on April 28, 1948, at New Haven, Conn. (at the North Eastern District meeting), and will hold a 1-day meeting at Boston, Mass., on May 3, 1949, and a 2-day session at Atlanta, Ga., on May 26–27, 1949. The paper industry was covered by a session at Milwaukee, Wis., on October 21, 1948 (at the Midwest general meeting); another one will be held at Swampscott, Mass., June 24, 1949 (during the summer general meeting). The machine tool group held technical sessions at Pittsburgh, Pa. (January 1948), at Milwaukee (October 1948), and is planning a 2-day session at Cincinnati in October 1949. The subcommittee on materials handling had one session at Pittsburgh (January 1948), at Milwaukee (October 1948), and will have a 1-day session at Cleveland (May 13, 1949). All sessions arranged outside of AIEE general or District meetings are arranged jointly with the local Sections of AIEE. Additional subcommittees to cover other industries will be organized in the near future.

The committee believes that this plan goes a long way toward filling the needs of electrical engineers in the industry and undoubtedly will draw them closer to the Institute.

* Chairman Umansky of the committee on general industry applications, his committee, and subcommittees merit special mention because of the number of successful technical committee conferences which they have conducted during the year and for the number they have planned for the future.

Committee on Industrial Control. (*J. D. Leitch, chairman; G. W. Heumann, vice-chairman; John A. Cortelli, secretary.*) A great deal of work has been done by this committee in the preparation of an exhaustive bibliography on industrial control and final abstracting now is nearing completion. Subcommittee activities include the following.

The subcommittee on Standards has completed a revision of AIEE Standard number 15 on industrial control, and the Standard is now in the hands of the Standards committee. The subcommittee on electronic control consists of five working groups which are very active in the field of definitions, working in co-operation with other interested groups. This same subcommittee sponsored a conference on industrial application of electron tubes at Buffalo, N. Y., in April.

The work of the test codes subcommittee is proceeding with a code on interrupting ability of magnetic contactors and has outlined a number of projects for future action. The joint subcommittee on servomechanisms has worked in close co-operation with the parent committee in sponsoring joint sessions at AIEE national meetings. This subcommittee is very active and is working closely with the subcommittee on electronic control on definitions of common interest.

Radiant Heating Committee. (*Paul H. Goodell, chairman; C. E. Russell, secretary.*) Members of the AIEE radiant heating committee made inspection trips to Leeds and Northrup Company and the Brown Instru-

ment Division of the Minneapolis-Honeywell Company during their recent 2-day conference in Philadelphia, Pa. The conference and inspection trips were arranged by Charles E. Russell of the Philadelphia Electric Company. P. O. Blackmore is publicity chairman for the committee. C. T. Prendergast of the Western Electric Company is in charge of the committee activities on process control.

New types of electronic instruments were inspected for recording actual product temperatures as used for curing protective coatings, water evaporation, and other industrial processing requirements. Some of the instruments were able to indicate temperature by simply viewing, or collecting infrared radiation from the heated products by means of special lens and thermopile equipment, while others used new types of resistance elements resembling postage stamps, which were stuck to the surface of the product with a high-temperature silicone cement. The committee is co-operating with leading instrument manufacturers in determining requirements and improved methods for controlling heating processes where air temperature and other indirect means cannot be successfully employed.

Power Group

Insulated Conductor Committee. (*L. F. Hickernell, chairman; H. Halperin, vice-chairman; C. T. Hatcher, secretary.*) Created in August 1947, this committee, organized into 12 standing subcommittees, has sponsored 19 papers, presented at five general meetings and one District meeting. Committee meetings, of which four have been held, have grown from 1- to 2-day sessions, the first day being devoted to individual subcommittee meetings. The subcommittees have considered 73 projects, ten of which have been completed and 59 remain active.

Some of the projects under study are as follows.

Standard number 30 (1944), "American Standard Definitions and General Standards for Wire and Cable", is being revised to form basis for the revision of "American Standard Definitions of Electrical Terms" (American Standards Association Standard *C42*). The economical choice between a conventional duct-cable installation and the newer pipe-cable system largely is dependent upon the relative current-carrying capacities. Much data are available for the former system but until recently, very little on the latter, which depends to a great extent upon the value assumed for the soil thermal resistivity. Guided by subcommittee discussion, four papers have been presented on this subject.

Other problems accompanying the pipe-cable system, such as a-c losses, and the hydraulic aspects are being studied. The installation details of new designs of extra-high-voltage cable systems are being presented in sponsored papers. A questionnaire on the subject of protective coverings for lead sheaths to mitigate corrosion is being circulated. Comments on the new Standard number 48 (1948) on cable potheads are being collected to form the basis of a future revision when required. Due to the wider use of limiters on a-c network systems, consideration is being given to the publication of a new Standard on cable limiters.

Papers are being sponsored on the fundamental design characteristics of low- and high-voltage potheads and joints. Appurtenances to the underground cable system such as conduit and manhole construction, transformer vault design and ventilation, and underriver crossings, heretofore neglected by AIEE, are being reviewed and papers on present-day engineering practice being prepared. A new "Test Code for Paper-Insulated Power Cables" is in the course of preparation.

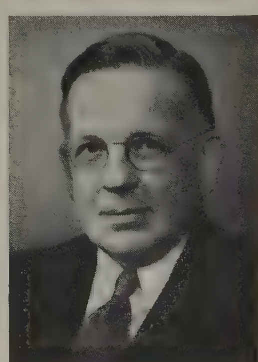
Committee on Switchgear. (*F. A. Lane, chairman; Otto Naef, secretary.*) Considerable progress has been achieved by working groups and subcommittees with the preparation of the following proposed new and revised Standards: "Automatic Circuit Reclosers for A-C Distribution Systems," "Switchgear Assemblies," "Fuses above 600 Volts," "Combined Standard for Interrupter Switches," "Air Switches and Bus Supports." A "Guide for Application of Low-Voltage Air Circuit Breakers," fills a long wanted need. Part of this work is ready to be referred to the Standards committee while the rest will come up for main committee approval shortly. Other important work now in hand covers the revision of parts of the American Standards Association Standards for power circuit breakers, the study of technical questions regarding the rating and application of power circuit breakers, the study of high-voltage out-of-phase switching, and the preparation of a test code for low-voltage air circuit breakers.

PERSONAL NOTES.......

Ernest Walter Davis (A '15, M '21, F '34), chief engineer, Simplex Wire and Cable Company, Cambridge, Mass., has been named to serve on the AIEE board of directors. Born March 3, 1890, in Auburn, Maine, he is a graduate of the Massachusetts Institute of Technology, class of 1913. Joining the Simplex Company, immediately subsequent to his graduation, his entire working career has been spent with that organization. His designation during the years 1913–32 was that of assistant electrical engineer, following which period he was promoted to chief electrical engineer. In 1947, he was named chief engineer. For an 8-year interval, he also was engaged as an instructor in electrical engineering at the Franklin Union Evening School, Boston, Mass. During his last 17 years with Simplex, Davis has been in charge of all testing and development work in the factory and laboratories, has assisted in the formulation of specifications, and has handled contacts with electrical agencies. The author of many technical papers, some of which have been presented before AIEE meetings, he was vice-president of Institute District number 1 (North Eastern) 1946–48. Chairman of the AIEE Boston Section, 1927–28, Davis has served on the following committees: applications to marine work, 1939–40; transmission and distribution, 1939–43; electric welding, 1946–48; insulated conductors, 1947–49; and mining and metal industry, 1947–49. In addition, he is a representative on the Engineers' Council for Professional Development, his term of office being 1947–50. A member of the American Standards Association and the British Institute of Electrical Engineers, he also has been associated with the Insulated Power Cable Engineers Association of the National Research Council.

E. C. Day (A '43), formerly technical co-ordinator, pilotless plane division, Fairchild Engine and Airplane Corporation, Farmingdale, N. Y., is now secretary of both the AIEE technical program committee and the AIEE committee on the award of Institute prizes, AIEE headquarters, New York, N. Y. He replaces Charles S. Rich who is now editor of AIEE publications. Born June 17, 1912, in Jersey City, N. J., Day received his bachelor of science degree in electrical engineering from New York University in 1933. For the next four years, he was on the electric equipment staff, testing department, of the Consolidated Edison Company of New York. From 1937 to 1938, Day was a junior engineer with the Western Electric Company, Kearny, N. J., and then spent two years as watt-hour meter inspector with the Ivan T. Johnson Company of New York City. From 1940 to 1941, he again returned to quality control work with the Western Electric Company, this time on telephonic equipment. In 1941, Day joined the Camp Evans Signal Laboratory, Belmar, N. J., as associate radio engineer. In this capacity, he was responsible for the procurement and in-

F. E. Harrell



E. W. Davis

E. C. Day

spection of Signal Corps radio equipment. He remained with the Signal Laboratory until 1943, when he resigned to go with the Templetone Radio Company, Mystic, Conn., as assistant to the director of engineering. In 1944, he became associated with the Federal Telecommunications Laboratories, Nutley, N. J., as administrative assistant to the radar project engineer. He was with the Fairchild Corporation from 1946 to 1948, coming to the AIEE headquarters staff in October of that year. In his new position, as secretary of the technical program committee, Day will conduct all the correspondence between authors and committees dealing with the review of technical papers to be presented at AIEE meetings and for publication. In addition, he will co-ordinate the scheduling of sessions at the general meetings of the Institute, and will arrange for the submission of written discussions of the formal technical papers. As secretary of the committee on the award of Institute prizes, Day will prepare the certificates and prizes to be given to the winners of Branch, District Branch, and Institute awards. Furthermore, he will arrange for the review of those papers eligible for Institute prizes for submission to the committee.

F. E. Harrell (A '26, M '35, F '40), manufacturing vice-president of Reliance Electric and Engineering Company, Cleveland, Ohio, has been named to the chairmanship of the AIEE Standards committee, a post formerly held by the late R. L. Jones. A native of Logansport, Ind., Harrell was born October 29, 1903. Following his graduation from Purdue University in 1924, he joined the Chicago office of the Reliance Electric and Engineering Company as a sales engineer. Promoted to design engineer three years later, he was placed in charge of the company's mechanical-design section in 1927. Named to supervise Reliance's a-c design department in 1932, he became assistant chief engineer two years later, a full-fledged chief engineer in 1943, and general works manager in 1945. Elected to the company's board of directors in 1946, he attained his present position one year later. During the early part of the war, Harrell served as executive director of Reliance's marine division. Active in the AIEE, he has been a member of the following AIEE committees: applications to iron and steel products, 1934–38; electric machinery, 1936–47 (chairman, 1942–44); award of Institute prizes, 1942–44; Lamme Medal 1947–present (term of office ends in 1950); Standards, 1942–46 (ex officio), 1948–49, (chairman, January–August 1949); technical program, 1942–44, January–August 1949; planning and co-ordination, January–August 1949. At present, he is serving also on the Standards Council of the American Standards Association, and is slated to serve thereon until the year 1951. Formerly chairman of the Cleveland section of the Institute (1937–38), he is a member of the American Society of Naval Engineers and the Cleveland Engineering Society.

G. W. Almassy (A '43), Los Angeles, Calif.; **A. Hansen, Jr.**, (A '37, M '45), **L. I. Mendelsohn** (A '41, F '45), **H. E. Trekell** (A '35, M '36), and **J. H. Wright** (A '33, M '43), all four of West Lynn, Mass.; **R. Lamborn** (A '26, M '48) and **I. W. Lichtenfels** (A '41), both of Erie, Pa.; **G. E. Nonken** (A '36, F '45) and **W. O. Solberg** (A '41), both of Pittsfield, Mass.; and **H. T. Seeley** (A '27) of Philadelphia, Pa., all General Electric Company employees, have received the Charles A. Coffin Award for work of outstanding merit during 1948. A member of the AIEE air transportation committee, Almassy was cited for "his outstanding initiative and ingenuity in designing and testing an improved aircraft electric power system." A group award was made to Hansen, Mendelsohn, Trekell, and Wright for their "application of technical knowledge in the development of a new single-phase watt-hour meter." Lamborn was honored for his "design improvements of d-c generators for a Diesel-electric locomotive." "Ingenuity and determination in the design of control equipment for heavy subway cars" brought Lichtenfels his award. Nonken and Solberg were cited for "the development of equipment and methods which made possible, for the first time, high-quality low-cost cast glass bushings." The development of "high-speed differential protection, using standard bushing current transformers and standard-energy high-impedance relays," was Seeley's award-winning achievement.

W. H. Martin (A '14, F '30), **D. A. Quarles** (A '23, F '41), and **J. W. McRae** (A '37) all have new positions as a result of Bell Telephone Laboratory changes. In the New York organization, Martin has been named vice-president. Quarles, also a vice-president, has assumed charge of staff functions handled by the late R. L. Jones, and McRae, who is to succeed Quarles, will be in charge of the development of transmission, switching, and electronic apparatus. McRae joined the laboratory in 1937. Martin and Quarles, who have been with the Bell System, for four and three decades, respectively, both have been active in the AIEE, Martin having served on the Standards committee, 1925–33. Quarles has served on the following committees: finance, 1944–48 (chairman, 1946–48); Edison Medal, 1945–47; electronics, 1945–47; instruments and measurements, 1945–46; planning and co-ordination, 1946–48; headquarters, 1946–48; Lamme Medal, 1947–present; management, 1948–present; library board, United Engineering Trustees, 1945–46; and board of trustees, AIEE retirement system, 1945–48.

P. H. Thomas (A '00, F '12), has retired from the Federal Power Commission, Washington, D. C., after some 15 years' service with the government. An alumnus of the Massachusetts Institute of Technology, he joined the engineering department of the Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pa., in 1893. Later becoming chief engineer with the Cooper-Hewitt Electric Company, he established his own consulting office in New York City in 1907. From 1916 to 1928, he was consulting engineer to the firm of Guggenheim Brothers. For the 6-year period prior to his appointment to the Federal Power Commission in 1934, he was an independent consulting engineer. Specifically, Thomas had worked in the National Power Survey section of the Commission, having been chief of the power requirements division as well as regional director with offices at Atlanta, Ga. The following is a partial list of Thomas' AIEE committee memberships: electrophysics; meetings and papers (now, technical program); Standards; power transmission and distribution; award of Institute prizes; Lamme Medal; and Edison Medal. He is an AIEE Member for Life.

H. A. Affel (A '18, F '41), Bell Telephone Laboratories, New York, N. Y.; **F. E. d'Humy** (A '20, F '30), Western Union Telegraph Company, New York, N. Y.; **F. W. Grover** (A '21, M '30), Union College, Schenectady, N. Y.; **E. A. Guillemin** (A '24), Massachusetts Institute of Technology, Cambridge, Mass.; **L. C. Holmes** (A '31, M '43), Stromberg-Carlson Company, Rochester, N. Y.; **J. K. Johnson** (A '28, M '44), consulting engineer, New York, N. Y.; and **H. J. Reich** (A '32, M '43), Yale University, New Haven, Conn., have received fellowship awards from the Institute of Radio Engineers. Affel has served on the following AIEE committees: communication; technical program; Standards; award of Institute prizes; and the now defunct radio technical planning board. A past member of the former telegraphy and telephony committee, d'Humy at present is on the board of examiners. Holmes has been associated with the communication committee for the last two years.

Philip Sporn (A '20, F '30), president of the American Gas and Electric Service Corporation, New York, N. Y., has retired as head of the Atlantic City (N. J.) Electric Company. He had been president of the latter company since 1947. An active AIEE member, Sporn has served on the following committees: transmission and distribution; research; production and application of light; power generation; technical program; Standards; award of Institute prizes; and Lamme Medal. At present, he is serving on the Edison Medal committee, his term due to expire in 1953.

A. G. Wambach (M '46), engineer, American Telephone and Telegraph Company, New York, N. Y., recently was awarded the Army-Navy certificate of appreciation for his contribution to the work of the Office of Scientific Research and Development during World War II. Wambach directed the expendable radio sono buoy project. Stationed at the Navy's underwater sound laboratory at New London, Conn., he operated with carrier-based and bomber squadrons on the North and South Atlantic sea frontiers. Wambach also has been recommended for the Medal of Merit by the Commander Air Force—Atlantic Fleet.

G. H. Schaeffer (A '11), formerly associated with the Carpenter Steel Company, Reading, Pa., has opened a consulting engineering office in the same city. Having over four decades of experience in the steel-mill field, he will specialize in industrial and municipal work covering all phases of electric power and heat and process applications. Schaeffer is a past president of the Institute of Iron and Steel Engineers.

G. I. Wallace, Jr. (A '47), a sales engineer for several years with Russel Ranson, Charlotte, N. C., has become a partner in the business, to be known henceforward as Ranson, Wallace and Company. The firm is a manufacturers' representative, dealing with several large concerns in North and South Carolina, and Virginia. An electrical engineering graduate of Washington and Lee University, Wallace spent seven years as design engineer with the Duke Power Company in Charlotte, followed by three years as radar and communications engineer in the Army Signal Corps.

W. J. Delehanty (A '17, M '24), formerly sales manager of the works and apparatus department, General Electric Company, Oakland, Calif., has been transferred to a similar position in the company's wire and cable division. In another General Electric change, **G. B. Shanklin** (A '16, F '46), has been named manager of commercial engineering for electrical utilities for the wire and cable division of the construction and materials department at Schenectady, N. Y. Formerly, he held an analogous position in the apparatus department. The two men have seen almost the same length of service with the organization, Delehanty having joined General Electric in 1910 and Shanklin having joined one year later. Shanklin has belonged to the AIEE power transmission and distribution committee and has been a member of the insulated conductors committee for the last two years.

G. L. MacLane, Jr., (A '40) has been named assistant manager of the engineering laboratories and standards department and **L. J. Berberich** is the new manager of the liaison section of this department, at the Westinghouse Electric Corporation, East Pittsburgh, Pa. Both men received their undergraduate degrees in 1928, MacLane at the California Institute of Technology and Berberich at Johns Hopkins University. On the staff of the University of Arizona, 1928–34, MacLane was with the Central Arizona Light and Power Company for two years, subsequently joining Westinghouse. Berberich worked six years for the research and development laboratories of the Socony Vacuum Oil Company, becoming associated with Westinghouse in 1937. Berberich served on the AIEE research committee, 1937–40.

K. N. Mathes (A '36, M '43), electrical engineer and research associate in biology, Rensselaer Polytechnic Institute, Troy, N. Y., is slated to work on a one-to-two-year research project, financed by the United States Army Signal Corps, Fort Monmouth, N. J. R. H. Luce, head of Rensselaer's biology department and well-known as an industrial microbiologist, will be in charge of the project, for which $37,300 has been allotted during 1949. Mathes and his associates hope to develop an improved electronic-wiring insulation, of which a fungicide will be an important ingredient. They will apply their findings to the protection of electronic apparatus against extreme conditions of temperature and humidity.

D. M. Umphrey (A '36, M '43), formerly head of the development engineering department, Pacific Electric Manufacturing Corporation, San Francisco, Calif., has been named chief engineer of that organization. A graduate of Oregon State College, Umphrey has done engineering work in the water-supply and electrical central-station fields. Among the designs that can be credited to him is an interruptor which enabled an oil circuit breaker, in a recent test, to interrupt 9,600,000 kva at 230 kv on a 3-phase basis.

F. H. Rockett (A '47), formerly an associate editor of *Electronics*, published by McGraw-Hill Publishing Company, Inc., New York, N. Y., has joined the staff of the Airborne Instruments Company, Mineola, N. Y. In his new position, he will assist in editing and reviewing research reports put out by the laboratory. An electrical engineering graduate of Lehigh University, class of 1942, Rockett has worked on the staffs of both his alma mater and Columbia University. He became associated with *Electronics* in 1944.

R. H. Nau (A '40), professor of electrical engineering, University of Illinois, Urbana, has been decorated by the Chinese government with the "Special Breast Order of Yun Hui with Ribbon," in recognition of his war services. A native of Hillsboro, Iowa, Nau was stationed in China from 1944 to 1946, as a major with American forces attached to the 94th Chinese army. Commanding 70 American officers engaged in instructing Chinese signal officers, Nau was later with American troops occupying Shanghai and Formosa.

R. L. Merrill (A '40), former electrical engineer with the Curtiss-Wright Corporation, Columbus, Ohio, has been named to the staff of the Battelle Institute in the same city. The holder of bachelor and master degrees from Ohio State University, he is a member of the Institute of Radio Engineers and two honorary engineering societies, Tau Beta Pi and Sigma Xi.

Edwin Hansson (A '19, F '45), retired recently from his position of transmission engineer with the Pennsylvania Water and Power Company, Baltimore, Md. Chairman of the AIEE Maryland Section, 1947–48, he served on the Institute's transmission and distribution committee, 1931–48.

F. E. Reeves (A '45) has joined Fay, Spofford and Thorndike, Boston Mass., as electrical design engineer, his responsibilities to be the design of electric power plants. Formerly associated with the Boston Edison Company, Reeves was appointed electrical engineer of the Electrical Apparatus Company in the same city in 1944.

T. R. Weichel (M '46), formerly with the United States Bureau of Mines, is now a mining electrical engineer for the sales department of the Hazard Insulated Wire Works Division, The Okonite Company, Wilkes-Barre, Pa. He is serving on these AIEE committees: mining and metal industry, 1947–49; Standards, 1946–49.

F. E. Baker (A '40), former section engineering manager of the specialty transformer department, Westinghouse Electric Corporation, Sharon, Pa., has been promoted to manager of the same department. A graduate of Bucknell University, class of 1925, he joined Westinghouse as a graduate student, later being named to the positions of design engineer and section engineer, successively.

T. G. Glenn (A '28, M '38), engineer of the Detroit office, General Electric Company, Detroit, Mich., has been appointed manager of the engineering division of the company's newly-created Michigan district. He has been with General Electric since 1922.

A. R. Hines (A '45) will be manager of the new Michigan sales district of the apparatus department of the General Electric Company, and will have as assistant managers, **V. J. Snyder** (A '40) and **C. M. Dunn** (A '42). Their headquarters will be in Detroit.

P. N. Ross (A '45), formerly assistant director of the power pile division, Oak Ridge National Laboratories, Tenn., has been appointed assistant director of research for the atomic power division, Westinghouse Electric Corporation, Pittsburgh, Pa.

G. U. Parks (M '30), formerly general manager of the Montaup Electric Company, Fall River, Mass., a position he held for the past 24 years, has been appointed assistant superintendent of production, steam stations, Boston (Mass.) Edison Company.

W. H. Stueve (M '43), executive assistant, Oklahoma Gas and Electric Company, has been given an award by the Petroleum Electric Power Association for his outstanding work and services in applying electric power to the petroleum industry during the past 25 years. Stueve has been a member of the AIEE special committee on the registration of engineers, 1943–46.

C. T. Shoch (M '48), manager of the industrial sales department of the Pennsylvania Power and Light Company, Allentown, Pa., has been elected chairman of the Interstate Power Club of New York. He has been with the Pennsylvania utility since 1924, except for a five year period spent as a consulting engineer.

G. F. Maedel (M '45), superintendent of Radio Corporation of America Institutes, Inc., New York, N. Y., has been elected vice-president and general superintendent. Joining RCA Institutes in 1933, he was the first instructor in the mathematics department. A licensed professional engineer in New York state, he is also the author of two textbooks on mathematics which are in use at RCA Institutes.

R. L. Mansur (A '44), formerly on the engineering staff, Westinghouse Electric Corporation, has joined the eastern division staff of the Line Material Company, at Cambridge, Mass. He is presently a member of the executive committee of the AIEE Boston Section, and has served as chairman of that Section's membership committee.

G. A. Caldwell (M '48), exchange plant engineer, Bell Telephone Company of Canada, Toronto, Ontario, Canada, has been returned by acclamation as a councillor of the Association of Professional Engineers of the Province of Ontario.

P. H. Trickey (A '20, F '47), formerly chief engineer for the Diehl Manufacturing Company, now is associated with the Vickers Electric Division of Vickers, Inc., St. Louis, Mo., and will be in charge of rotating electromagnetic machinery. He has been a member of the AIEE rotating machinery committee since 1946.

J. H. Smith (A '42) is now manager of the apparatus division, Toronto district, for the Canadian General Electric Company, Toronto, Ontario, Canada.

F. W. Russell (A '26), formerly assistant general superintendent, has been promoted to general superintendent of the Louisville (Ky.) Gas and Electric Company.

F. D. Troxel (A '26, M '40) recently was appointed as a partner and as senior electrical engineer for the Vern E. Alden Company. He was a member of the AIEE power generation committee from 1943 to 1945.

B. H. Cutler (M '40), formerly chief engineer, L. E. Meyers Company, Chicago, Ill., has been elected vice-president of the Muncie Construction Corporation, Muncie, Ind. He has had considerable experience in transmission line design.

D. G. Wilson (A '47), on the faculty of the University of Kansas, Lawrence, since 1947, has been appointed chairman of the department of electrical engineering.

R. M. Darrin (A '28, M '34), manager of the central stations divisions, apparatus department, General Electric Company, Schenectady, N. Y., has been elected a commercial vice-president of that company. He has been with General Electric since 1919, and was formerly in that firm's transformer division from 1919 to 1929.

OBITUARY • • • • • •

Edwin Henry Colpitts (A '11, M '11, F '12) retired vice-president of the Bell Telephone Laboratories, New York, N. Y., died March 6, 1949. Born January 19, 1872, in Pointe du Butte, New Brunswick, Canada, Colpitts received two bachelor of arts degrees, one from Allison University in 1893, and the other from Harvard University in 1896. After two years at the latter university as a Donald Bethune assistant in physics, he was granted a master of arts degree. In 1899, Colpitts joined the American Bell Telephone Company of Boston, Mass., as an engineer in the mechanical engineering department, which later was merged with the American Telephone and Telegraph Company. Following Doctor Michael I. Pupin's discovery at the turn of the century, that the proper spacing of coils along the telephone circuit was the key to transmission efficiency, Colpitts helped to apply Pupin's theory of electrical loading to practical usage. Colpitts' work in this, as well as other, fields led to the development of long-distance wire and radio communication systems, including the installation of trans-Atlantic telephone service. In addition, he devoted much of his time to research on telephone repeater tubes, which actuate weak telephonic currents without appreciable loss in voice transmission. In 1907, Colpitts became a research engineer with the Western Electric Company, New York, N. Y. Named head of the engineering department's research branch in 1911, he was made assistant chief engineer six years later. Returning to the American Telephone and Telegraph Company in 1924 in the capacity of assistant vice-president in the department of development and research, he became vice-president of the Bell Telephone Laboratories ten years later. After Colpitts retired, in 1937, he remained active in scientific work, being appointed a director of the Engineering Foundation in 1941. He also was decorated by Emperor Hirohito with the Fourth Order of Merit of the Sacred Treaure for delivering the Idware lectures, sponsored by the Japanese Institute of Electrical Engineers, in Japan soon after his retirement. In 1948, he was the recipient of the Elliot Cresson Medal of Franklin Institute, Philadelphia, Pa., for his contribution to long-distance telephony. Holder of more than a score of patents on telephonic inventions, the best-known of which is the Colpitts vacuum-tube oscillator, he is the author of several articles on his specialty, some of which have appeared in AIEE *TRANSACTIONS*. An AIEE Member for Life, he served on four committees: Standards, 1916–18; telegraphy and telephony, 1919–24; research, 1922–37; and the Members-for-Life fund, 1944–47. He was a fellow in the following organizations: the Institute of Radio Engineers; the American Physical Society; and the Acoustical Society of America. In addition, he belonged to the American Association for the Advancement of Science, and the American Chemical Society.

Harvey Clayton Rentschler (M '40), retired director of research of the Westinghouse Electric Corporation, Bloomfield, N. J., whose early investigations into the properties of electric-lamp filaments were instrumental in the successful development of the atomic bomb, died March 23, 1949. The relationship between electric lamps and the bomb is explained by the fact that some 30 years ago Rentschler thought that possibly uranium might serve as a more efficient emitter of light than tungsten. At the time that he joined Westinghouse, 1917, virtually nothing was known about the properties of uranium. In order to study its lamp-filament possibilities, Rentschler and his assistant, J. W. Marden, set about refining the metal. In 1922, they succeeded in obtaining it in the pure state, but subsequently found that it was inferior to tungsten in its light-emitting efficiency. As a result of their work, however, Rentschler and his associates became known as uranium-refining "experts." This led A. H. Compton of the University of Chicago Metallurgical Project Office to call upon Westinghouse, in 1942 to produce three tons of refined uranium for atomic-bomb experimentation. Setting up a small "factory" within their laboratory, Rentschler's group, within a few months, stepped up their uranium output from eight ounces to more than 500 pounds daily thereby filling Chicago's needs. Born March 26, 1881, in Hamburg, Pa., Rentschler received his bachelor's and master's degrees from Princeton University in 1903 and 1904. Granted his doctorate in 1908, he joined the teaching staff of the University of Missouri at Columbia in the same year, remaining there until 1917. After his retirement from Westinghouse in 1947, Rentschler served as a visiting professor of engineering at Princeton (N. J.) University. Developer of the steri-lamp, first practical bacteria-killing lamp, he held more than 100 patents, principally in the field of electronics. The author of technical papers on the properties of gases and rare metals, and the ultraviolet light meter, he served on two AIEE committees: electronics, 1942–43; and applications of electricity to therapeutics, 1942–46. A member of the American Optical Society, the American Physical Society, and the New York Electrical Society, he also belonged to the American Association for the Advancement of Science.

Joseph Willard Milnor (A '13, M '23, F '30), retired consulting engineer, Western Union Telegraph Company, New York, N. Y., died March 30, 1949. Born October 25, 1889, in Williamsport, Pa., he received an electrical engineering degree from Lehigh University in 1912. Joining the General Electric Company, Pittsfield, Mass., in the year of his graduation, he was employed by Western Union in 1913. In the capacity of research engineer, 1919–36, one of his achievements during that time was the design of a high-speed duplex submarine telegraph cable, which was laid from Newfoundland to the Azores in 1928. This cable provided 2-way operation at a speed approximately four times that of any duplex cable previously laid. Appointed transmission engineer in 1936, Milnor subsequently was placed in charge of the development of system now in service for the sending of photographs by submarine cable from London to New York. Named consulting engineer in 1944, he retired from Western Union several months later. Awarded the 1940 AIEE national prize for the best paper on engineering practice, entitled "Control of Inductive Interference to Telegraph Systems," he had written many papers on cable and other transmission problems. A member of the American Association for the Advancement of Science, Tau Beta Pi, and the Institute of Radio Engineers, he served on the following AIEE committees: communication, 1929–34; protective devices, 1937–42; and the board of examiners, 1948–49.

Albert C. Wood (A '10, M '45), consulting engineer, Philadelphia, Pa., died March 13, 1949. A native of Fayetteville, Ark., born February 21, 1874, he received his bachelor's degree at the age of 18 from the University of Arkansas. In 1943, he was granted an honorary doctorate from the same institution. Subsequent to his graduation, he

joined J. J. deKinder, consulting engineer, Philadelphia, and eight years later, he was working under the firm name of deKinder and Wood. In 1902, he opened his own consulting engineering office, continuing to operate it until the time of his death. Primarily, Wood did power and industrial plant-engineering work, wherein he often supervised the construction and installation of mechanical, hydraulic, steam, and electric equipment. He was a member of the American Society of Mechanical Engineers and the Engineers Club of Philadelphia.

MEMBERSHIP . .

Recommended for Transfer

The board of examiners at its meeting of March 17, 1949, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections must be furnished and will be treated as confidential.

To Grade of Fellow

Beller, C. J., genl. supt. electrical operations & engg., The Cleveland Electric Illuminating Co., Cleveland, Ohio
Johnson, W. N., mgr. frequency change dept., Southern California Edison Co., Los Angeles, Calif.
Jolliffe, C. B., executive vice-pres., RCA in chg. RCA labs. div., New York, N. Y.
Lewis, C. H., distribution engr., Public Service Elec. & Gas Co., Newark, N. J.
Luce, D. C., vice-pres., chg. of elec. operation, Public Service Elec. & Gas Co., Newark, N. J.
Miller, K. W., asst. director of research, Armour Research Foundation, Chicago, Ill.
Nippes, I. S., mgr. naval dept., Elliott Co., Ridgway, Pa.
Noble, P. O., mgr. engg. frac.-hp motor div., General Elec. Co., Fort Wayne, Ind.
Parrack, V. R., supervisor elec. engg., Florida Power Corp., St. Petersburg, Fla.
Sleeper, H. P., operating engr., Public Service Elec. & Gas Co., Newark, N. J.
Snyder, E. H., asst. chief engr., elec. engg. dept., Public Service Elec. & Gas Co., Newark, N. J.
Sprague, R. C., pres., Sprague Elec. Co., North Adams, Mass.
Vaitses, G. S., senior elec. engr.; head, electrical dev. section Scientific Branch, U. S. Maritime Comm., Washington, D. C.
Waddington, C. V., chief engr., Kansas Gas & Elec. Co., Wichita, Kans.

14 to grade of Fellow

To Grade of Member

Allen, H. B., development engr., Electric Controller & Mfg. Co., Cleveland, Ohio
Bassett, H. L., requisition engr., General Electric Co., Phila., Pa.
Brewer, N. M., professional engr., Austin Co., Cleveland, Ohio
Coleman, J. B., asst. director of engg., RCA Victor div. of Radio Corp. of America, Camden, N. J.
Dasburg, A. V., communications engr., General Railway Signal Co., Rochester, N. Y.
Dow, C. O., application engr., The Electric Controller & Mfg. Co., Cleveland, Ohio
DeLerno, M. J., acting asst. prof. elec. engg., Newark College of Engg., Newark, N. J.
Fahnoe, H. H., design engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Fisher, M. H., industry engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
Holm, J. P., elec. engr., Commonwealth & Southern Corp., Jackson, Mich.
Kamm, L. J., engr., The Teleregister Corp., New York, N. Y.
Kennedy, E. D., asst. research engr., University of Florida, Gainesville, Fla.
Kirwan, J. G., consulting & application engr., Westinghouse Elec. Corp., Portland, Oreg.
Levine, D. L., senior engr., Commonwealth Edison Co., Chicago, Ill.
Merrell, T. Y., elec. engr., Corbin & Davis Electric Co., Phoenix, Ariz.
Ortiz, J. V., partner, Doyle & Ortiz, New York, N. Y.
Pierce, H. F., consulting engr., Maurice H. Connell & Associates, Miami, Fla.
Pullen, W. S., Jr., elec. engr., General Electric Co., Denver, Colo.
Rohrer, S. B., division traffic inspector, Western Union Telegraph Co., Chicago, Ill.
Schlegel, T. A., elec. engr., Gilbert Associates, Inc., Reading, Pa.
Short, C. M., elec. engr., dept. water & power, City of Los Angeles, Calif.
Siefert, P. H., pres., Wisconsin Electrical Mfg. Co., Milwaukee, Wis.
Starcke, O. A., sponsor engr., The United Light & Railways Service Co., Davenport, Iowa
Stromberg, T. V., chief engr., machinery engg. dept., ASEA, Vasteras, Sweden
Tholstrup, H. L., development engr., Commercial Controls Corp., Rochester, N. Y.
Thomas, K. E., transformer specialist, General Electric Co., Cleveland, Ohio
Walker, R. H., asst. elec. engr., Holyoke Water Pr. Co., Holyoke, Mass.
Warren, R. S., mgr., relay div., The Adams & Westlake Co., Elkhart, Ind.
Webb, H. J., application & sales engr., Photoswitch Inc., Cambridge, Mass.
Williams, H. E., (Lieut.), elec. engr., Royal Canadian Navy, Ottawa, Ontario, Canada
Wooley, R. L., radar engr., government div., General Electric Co., Syracuse, N. Y.

31 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before May 21, 1949, or July 21, 1949, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

Banavaliker, N. D., Government of West Bengal, Calcutta, India
Barber, I. J., Fostoria Pressed Steel Corp., Fostoria, Ohio
Bikshandeswaran, K. S., Arthur Hope College of Tech., Coimbatore, S. India
Carlson, E. W., Phaostron Co., South Pasadena, Calif.
Chattura, P. S., Military Engineers Services, Moradabade, United Provinces, India
Coleman, J. B., Univ. of Buffalo, Buffalo, N. Y.
Cornwell, F. E., Bureau of Reclamation, Denver, Colo.
Fairchild, A. C., N. Y. State Elec. & Gas Corp., Elmira, N. Y.
Forbes, S. G., Jr., General Elec. Co., Salt Lake City, Utah
Garik, S., Polytechnic Inst. of Brooklyn, Brooklyn, N. Y.
Ghose, H. C., Indian Ordnance Service, West Bengal, India
Gramm, A. F., Consumers Power Co., Jackson, Mich.
Gumpertz, D. G., Industrial Electronic Engineers, Los Angeles, Calif.
Hutchison, J. A., West Texas Utilities Co., Abilene, Tex.
Jones, G. E., G. E. Jones Elec. Co. Inc., Amarillo, Tex.
Jones, W. R., British Telephone Co., Vancouver, British Columbia, Canada
Krieger, G. E., West Coast Tel. Co., Everett, Wash.
Milne, J. W., Canadian General Elec. Co., Toronto, Ontario, Canada
Mitchell, R. J., British Columbia Tel. Co., Vancouver, British Columbia, Canada
Morgan, F. B., Wisconsin Tel. Co., Appleton, Wis.
Nagpurkar, G. M., Universal Engineering Co., Bombay, India
O'Donnell, J. J., Board of Education, Chicago, Ill.
Onslow, D. V., British Elec. & Allied Industries Research Assn., Leatherhead, Surrey, England
Pitsenberger, I. A., U. S. Engineers, Huntington, W. Va.
Popoff, N. I., French Tramway & Power Co., Shanghai, China
Richardson, R. McD., New Brunswick Tel. Co. Ltd., St. John, New Brunswick, Canada
Seaton, H. D., Southern Elec. Corp., North Chattanooga, Tenn.
Seguin, G. E., Westinghouse Elec. Intl. Co., New York, N. Y.
Smillie, P. V., Royal Electrical & Mechanical Engineers, London, England
Sommer, P. J., Stromberg-Carlson Co., Rochester, N. Y.
Spencer, H. H., Bell Tel. Labs., New York, N. Y.
Szporn, I., Rua 7 de Abril, 118 s.1202, Sao Paulo, Brazil, South America
Tessmann, A. H., Southern Elec. Corp., North Chattanooga, Tenn.
Turner, O. D., Consolidated Edison Co. of New York, Inc., New York, N. Y.
Wade, E. C., Mountain States Tel. & Tel. Co., El Paso, Tex.
Weybrew, S. F., Westinghouse Elec. Corp., St. Louis, Mo.
White, H. J., Research Corp., Bound Brook, N. J.
Wine, R. L., Chesapeake & Potomac Tel. Co., Washington, D. C.
Zilliax, G. R., British Tel. Co., Vancouver, British Columbia, Canada

39 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Ambusk, W. J., Rochester Inst. of Tech., Rochester, N. Y.
Bailey, W. N., Connecticut Valley Power Exchange, Hartford, Conn.
Barlow, D. P., General Elec. Co., Schenectady, N. Y.
Boaz, L. R., General Elec. Co., Pittsfield, Mass.
Clark, N. R., General Elec. Co., Pittsfield, Mass.
Conant, E. C., Jr., Elec. Service & Supply Co., Worcester, Mass.
Eldred, D., General Elec. Co., Schenectady, N. Y.
Gratton, R. E., General Elec. Co., Schenectady, N. Y.
Heckman, W. R., Clark Controller Co., Syracuse, N. Y.
Hill, I. A., Simplex Wire & Cable Co., Cambridge, Mass.
Howard, J. Y., General Railway Signal Co., Rochester, N. Y.
Keeler, O. F., Jr., Eastman Kodak Co., Rochester, N. Y.
Knowles, H. E., General Elec. Co., Schenectady, N. Y.
Kurtz, W. R., General Electric Co., Elmira, N. Y.
Latham, R. A., N.Y.S. Institute Applied Arts & Sciences, Binghamton, N. Y.
Lush, M. J., Rawson Electrical Instrument Co., Cambridge, Mass.
McGovern, E., General Elec. Co., Syracuse, N. Y.
McLean, H. T., General Elec. Co., Schenectady, N. Y.
McPheeters, D. W., Clarkson College of Tech., Potsdam, N. Y.
Nissel, H. E., Citizens Utilities Co., Greenwich, Conn.
Nunnally, J. R., General Elec. Co., Schenectady, N. Y.
Parkman, L. T., Westinghouse Elec. Corp., Boston, Mass.
Reed, G. W., Clarkson College of Tech., Potsdam, N. Y.
Shepherd, J. L., Stromberg-Carlson Co., Rochester, N. Y.
Shepp, J. H., Jr., General Elec. Co., Schenectady, N. Y.
Smith, J. F., General Elec. Co., Schenectady, N. Y.
Wexler, P. S. (Student), Syracuse Univ., Syracuse, N. Y.
White, H. F., Jackson & Moreland, Boston, Mass.
Yost, D. E., Univ. of Buffalo, Buffalo, N. Y.
Yunker, J. A., Jr., General Elec. Co., Schenectady, N. Y.

2. Middle Eastern

Alm, R., Taylor-Winfield Corp., Warren, Ohio
Ammerman, C. R., Penna. State College, State College, Pa.
Bateman, A. W., General Elec. Co., Philadelphia, Pa.
Bauman, N. P., United Engrs. & Const., Inc., Philadelphia, Pa.
Bennett, R. L., Electric Auto-Lite, Toledo, Ohio
Berryman, E. H. F., Pennsylvania Power & Light Co., Allentown, Pa.
Biggar, H. F., Jr., Reliance Elec. & Engg. Co., Cleveland, Ohio
Borror, G. M., Chesapeake & Potomac Tel. Co., Washington, D. C.
Bradley, R. G., Jr., Cleveland Elec. Illuminating Co., Cleveland, Ohio
Burmaster, C. U., General Elec. Co., Philadelphia, Pa.
Centa, J. A., 14314 Thames Ave., Cleveland, Ohio
Cenzori, J. D., Lewis Flight Prop. Lab., Cleveland Airport, Cleveland, Ohio
Clark, H., Allied Chemical & Dye Corp., Camden, N. J.
Conner, E. E., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Drollinger, J., Reliance Elec. & Engg. Co., Cleveland, Ohio
Fallows, A. N., Railway & Industrial Engg. Co., Greensburg, Pa.
Fannin, B. B., The Kellex Corp., Silver Spring, Md.
Ferguson, R. W., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Garber, J. R., (Miss), Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Glantz, L. M., U. S. Naval Air Development Station, Johnsville, Pa.
Glidewell, F. D., Dayton Power & Light Co., Greenville, Ohio
Griggs, F., Consolidated Coal Co. of W. Va., Fairmont, W. Va.
Harrison, S. E., Northern Penna. Power Co., Mansfield, Pa.
Hatcher, J. W., General Elec. Co., Philadelphia, Pa.
Horn, G. H., Line Material Co., Zanesville, Ohio
Howard, T. B., Welsbach Corp., Philadelphia, Pa.
Jackson, C. N., Jr., General Elec. Co., Philadelphia, Pa.
Johnson, T. D., Westinghouse Elec. Corp., Sharon, Pa.
Jones, R. F., Gilbert Assocs., Inc., Reading, Pa.
Jordan, W. R., Crise Mfg. Co., Columbus, Ohio
Joublanc, C. J., Line Material Co., Zanesville, Ohio
Lipman, S., Lipman Elec. Co., Inc., Baltimore, Md.
Losee, W. B., Jr., Naval Research Lab., Washington, D. C.
Mascone, A. A., Public Bldgs. Admin., Washington, D. C.
May, G. E., Metropolitan Edison Co., Reading, Pa.
McAdam, W., Leeds & Northrup Co., Philadelphia, Pa.
McCray, W. V., Rural Electrification Admin., Washington, D. C.
McDaniel, R. R., Virginian Railway Co., Princeton, W. Va.
Merrell, B. C., Procter & Gamble, Cincinnati, Ohio
Miller, J., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Moore, V. A., Jr., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Moran, J. P., Potomac Elec. Power Co., Washington, D. C.
Mulry, E. F., Trans World Airline, New Castle, Del.
Mutschler, W. H., Jr., Allis-Chalmers Mfg. Co., Pittsburgh, Pa.
Palmer, F. E., General Tire & Rubber Co., Akron, Ohio
Perdue, W. E., Chesapeake & Potomac Tel. Co. of Baltimore City, Baltimore, Md.
Phillips, J. H., Rural Electrification Admin., Washington, D. C.
Reed, R. B., Reliance Elec. & Engg. Co., Cleveland, Ohio
Rohde, H. D., Pennsylvania Elec. Co., Johnstown, Pa.
Rowe, W. O., U. S. Fidelity & Guaranty Co., Cincinnati, Ohio
Rumble, C. B., Jr., Allis-Chalmers Mfg. Co., Charleston, W. Va.
Sage, T. C., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Sinnott, J., Sylvania Elec. Products, Inc., Emporium, Pa.

Slimm, A. W., General Cable Corp., Philadelphia, Pa.
Smith, V. L., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Spengel, W. J., Naval Air Development Station, Johnsville, Pa.
Sprague, W. R., Duquesne Light Co., Pittsburgh, Pa.
Tekamp, D. G., Instrument Service Engg. Lab., Dayton, Ohio
Thompson, F. C., I.B.M. Corp., Washington, D. C.
Treffinger, H. H. (re-election), Baltimore & Ohio, Baltimore, Md.
Turhan, M., Brush Development Co., Cleveland, Ohio
Viera, F., Jr., Brown Instrument Co., Philadelphia, Pa.
Warner, R. S., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Young, R. J., Westinghouse Elec. Corp., Meadville, Pa.

3. New York City

Berntsen, C. E., Eastern Air Devices, Brooklyn, N. Y.
Buchaca, N. J., Arma Corp., Brooklyn, N. Y.
Carp, G., Ward Leonard Elec. Co., Mt. Vernon, N. Y.
Chipinski, L. T., Burns & Roe Co., New York, N. Y.
Chisholm, R. J., Consolidated Edison Co., New York, N. Y.
Ciemnecki, H. F., Standard Oil Development Co., Elizabeth, N. J.
Duckworth, L. A., N. Y. State Elec. & Gas Corp., Brewster, N. Y.
Fetig, J. E., Altec Service Corp., New York, N. Y.
Fliderblum, D., Radio Communications Engg. Co., New York, N. Y.
Forder, J. B., Federal Tel. & Radio Corp., Clifton, N. J.
Gould, R. H., Long Island Lighting Co., Roslyn, N. Y.
Kart, J. H., Burndy Engg. Co., New York, N. Y.
Lais, L. (Student), Polytech. Inst. of Brooklyn, Brooklyn, N. Y.
Laval, C. J., Bruce Elec. Co., Inc., New York, N. Y.
Lipinski, M. G., M. W. Kellogg Co., New York, N. Y.
Manfredonia, S. S., Board of Transportation, New York, N. Y.
McConnachie, W., Long Island Lighting Co., Garden City, N. Y.
Nagel, W. J., A. Neri, Inc., Hoboken, N. J.
Neuhardt, F. H. (re-election), Clark Controller Co., New York, N. Y.
Nothelfer, J. J., Nothelfer Winding Laboratories, Trenton, N. J.
Pendery, D. W., I.B.M. Corp., New York, N. Y.
Reps, D. N., Ford, Bacon & Davis, Inc., New York, N. Y.
Rice, R. J., Belmont Elec. Co., New York, N. Y.
Rosett, E., Sightmaster Corp., New Rochelle, N. Y.
Stevens, D. R., Jr., John A. Roebling's Sons Co., Trenton N. J.
Treibis, A., Dept. of Water Supply, Gas & Elec., New York, N. Y.
Wendler, H. J. (re-election) Public Service Elec. & Gas Co., Newark, N. J.
Wible, E. R., Bell Tel. Labs., Murray Hill, N. J.
Zlowe, L. O., Burndy Engg. Co., New York, N. Y.

4. Southern

Agnor, G. L., U. S. Atomic Energy Comm., Oak Ridge, Tenn.
Andrews, L. M., Charleston Naval Base, S. C.
Belet, J. J., I.B.M. Co., Winston-Salem, N. C.
Bell, W. A., Jr., T.V.A., Chattanooga, Tenn.
Bessent, J. K., Southern Elec. Service Co., Spartanburg, S. C.
Boyles, R. E., Tennessee Coal, Iron & RR. Co., Birmingham, Ala.
Carter, J., James R. Kearney Corp. of St. Louis, Mo., Jacksonville, Fla.
Crawford, J. P., Memphis Light Gas & Water Div., Memphis, Tenn.
Crozier, H. W. (re-election), T.V.A., Chattanooga, Tenn.
Dykes, J. G., New Orleans Public Service Inc., New Orleans, La.
Fitch, J. B., New Orleans Public Service Co., New Orleans, La.
Gentle, E. C., Jr., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Horton, C. W., Alabama Power Co., Birmingham, Ala.
House, J. E., Jr., T.C.I. Co., Birmingham, Ala.
Howland, J. W., T.V.A., Knoxville, Tenn.
Humphreys, A. T., Jr., Carbide & Carbon Chemicals Corp., Oak Ridge, Tenn.
Kastanakis, J. H., Memphis Light, Gas & Water Div., Memphis, Tenn.
O'Neal, J. Y., Jr., Coal Iron & Railroad Co., Pratt City, Ala.
Ramsey, J. W., Southern Bell Tel. & Tel. Co., Birmingham, Ala.
Stewart, J. B., Aluminum Co. of America, Alcoa, Tenn.
Stockdell, R. P., Richardson-Wayland Elec. Corp., Roanoke, Va.
Tomlin, H. B., Jr., General Elec. Co., Atlanta, Ga.
Toole, P. C., U. S. Army Signal Corps, Camp Gordon, Ga.
Trogner, A. M., Jr., Southern Line Material Co., Birmingham, Ala.
Tucker, J. W., III, Power Elec. Co., Inc., Jackson, Miss.
Vandegrift, J., Alabama Power Co., Birmingham, Ala.
Winfrey, M. C., Aluminum Co. of America, Alcoa, Tenn.

5. Great Lakes

Anderson, G. W., Cutler-Hammer, Inc., Milwaukee, Wis.
Antonucci, J. A., Underwriters Labs., Chicago, Ill.
Bohl, R. C., Redmond Co., Owosso, Mich.
Borling, G. A., Automatic Elec. Co., Chicago, Ill.
Brown, R. G., Univ. of North Dakota, Grand Forks, N. Dak.
Bruning, W. H. (Student), Univ. of Minnesota, Minneapolis, Minn.
Buday, P. E., Cleaver-Brooks Co., Milwaukee, Wis.
Budlong, D. W., Jr., Standard Oil Co., Whiting, Ind.
Cheney, C. F. (Student), Univ. of Wisconsin, Badger, Wis.
Christian, R. L., Illinois Commercial Tel. Co., Springfield, Ill.
Dols, K. K., Northern States Power Co., Minneapolis, Minn.
Fisher, L. M., Motorola, Inc., Chicago, Ill.
Foote, G. A., Illinois Commercial Tel Co., Paxton, Ill.
Garrett, R. H., Dynamatic Corp., Kenosha, Wis.
Gentile, R. F., City of Detroit, Detroit, Mich.
Gill, H. R., Jr., The Pyle-National Co., Chicago, Ill.
Hansen, R. C., 809 S. Fifth, Champaign, Ill.
Hiple, F. G., Northern Indiana Public Service Co., Michigan City, Ind.
Huard, A. W., Detroit Edison Co., Detroit, Mich.
Huffman, C. A., General Foods Corp., Battle Creek, Mich.
Jones, R. D., Robert E. Hattis, Consulting Engineers, Chicago, Ill.
Lacoss, L. C., Western Elec. Co., Duluth, Minn.
Liadis, J. G., 9693 Cascade Avenue Detroit, Mich.
Lindley, R. T., Allis-Chalmers Mfg. Co., West Allis, Wis.
McEachin, J. L., Minnesota Power & Light Co., Duluth, Minn.
Moberg, A. R., Jr., Illinois Bell Tel. Co., Centralia, Ill.
Peters, P. M., Great Lakes Steel Co., Detroit, Mich.
Rafel, G. A., G. A. Rafel & Co., Chicago, Ill.
Redden, E. T., Square D Co., Milwaukee, Wis.
Roy, H. W., Line Material Co., S. Milwaukee, Wis.
Salveson, E. O., Minnesota Power & Light Co., Minneapolis, Minn.
Tuntland, M. F., Public Service Co. of No. Illinois, Streator, Ill.
Walter, G. W., Standard Oil Co., Whiting, Ind.
Williams, R. A., Woodward Governor Co., Rockford, Ill.

6. North Central

Aberle, R. V., U. S. Bureau of Reclamation, Denver, Colo.
Andrews, J. H., Univ. of Colorado, Boulder, Colo.
McGee, D. A., Colorado Fuel & Iron Corp., Pueblo, Colo.
Olson, R. J., General Elec. Co., Omaha, Nebr.

7. South West

Angermeyer, L. C., Wagner Elec. Corp., St. Louis, Mo.
Ayers, R. C., Westinghouse Elec. Corp., St. Louis, Mo.
Baird, A. W., Gulf States Utilities Co., Port Arthur, Tex.
Benn, G. A., Houston Light & Power Co., Houston, Tex.
Benton, C. D., Continental Oil Co., Enid, Okla.
Black, H. L. (Student), Univ. of Kansas, Lawrence, Kans.
Bohannon, S. B., Federal Elec. Products Co., St. Louis, Mo.
Brown, C. Y., Gasoline Plant Construction Corp., Houston, Tex.
Chappell, A. R., C. P. Bobe Co., St. Louis, Mo.
Davidson, H. L., Black & Veatch Const. Eng., Kansas City, Mo.
Dodds, C. E., Dallas Power & Light Co., Dallas, Tex.
Duffy, J. A., Univ. of California, Sandia Lab., Albuquerque, N. Mex.
Earthman, W. L., Public Service Co. of Okla., Tulsa, Okla.
Elsloo, J. H., Nelson Elec. Mfg. Co., Tulsa, Okla.
Garrett, R. E., Tri-County Co-op., Lancaster, Mo.
Gaskill, M. B., Kansas City Power & Light Co., Kansas City, Mo.
Gates, R. B., Wagner Elec. Corp., St. Louis, Mo.
Geppert, D. V., Univ. of Arkansas, Fayetteville, Ark.
Gorman, F. W., Jr., F. W. Gorman, El Paso, Tex.
Grasshoff, L. H., A. & M. College of Texas, College Station, Tex.
Hamilton, R. S., Hamilton Elec. Shop, Prescott, Ark.
Hohlfeld, E. F., Federal Elec. Products Co., St. Louis, Mo.
Jeter, B. L., U. S. Army Engineers, Dallas, Tex.
Koether, C. K., Texas Elec. Service Co., Ft. Worth, Tex.
Kuellmer, V. A., Federal Elec. Products Co., St. Louis, Mo.
Lacy, L. A., Southwestern Public Service Co., Amarillo, Tex.
Levy, B., Univ. of Kansas, Lawrence, Kans.
Marshall, B. H., Westinghouse Elec. Corp., St. Louis, Mo.
McCord, F. E., Brown's Plumbing & Cabinet Shop, Norton, Kans.
McKee, J. B., Wagner Elec. Corp., St. Louis, Mo.
Nash, D. M., Jr., Magnolia Petroleum Co., Dallas, Tex.
Pharr, J. C., Jr., Reynolds Elec. & Engg. Co. Inc., Sante Fe, N. Mex.
Reime, P. W., Monsanto Chemical Co., St. Louis, Mo.
Scheufele, G. C., Black & Veatch, Kansas City, Mo.
See, E. M. (re-election), Route 1, Box 276E, Grand Prairie, Tex.
Sessen, G. V., General Elec. Co., St. Louis, Mo.
Stuttle, C. S., U. S. Engineer Office, Little Rock, Ark.
Thornton, J. H., Lion Oil Co., El Dorado, Ark.
Williams, A. M., Hollis W. Harris, Consulting Engineer, Amarillo, Tex.
Wyble, J. S., Westinghouse Elec. Corp., Amarillo, Tex.

8. Pacific

Babiracki, T. L., Kaelin Elec. Co., Los Angeles, Calif.
Begovich, T. S., Pacific Gas & Elec. Co., Mendota, Calif.
Bland, T. W., Schuckl & Co., Inc., Sunnyvale, Calif.
Boulton, V. R., Calif. Inst. of Tech., Pasadena, Calif.
Chinn, E. K. C., Stanford Univ., Stanford, Calif.
Craig, O. L., Dept. of Water & Power, Los Angeles, Calif.
Crill, P. D., Western Union Tel. Co., San Francisco, Calif.
Cruz, J. F., U. S. Army Corps of Engrs., c/o Postmaster, San Francisco, Calif.
DeCuir, L. E., Western Union Tel. Co., San Francisco, Calif.
Desjardins, S. E., Pacific Gas & Elec. Co., Oakland, Calif.
Graham, K. S., Pacific Gas & Elec. Co., Oakland, Calif.
Griffin, T. F., Pacific Gas & Elec. Co., Oakland, Calif.
Holman, S. E., North American Aviation, Los Angeles, Calif.
Hughes, J. S., The Texas Co., Los Angeles, Calif.
Longley, J. A., Jr., Allis-Chalmers Mfg. Co., San Francisco, Calif.
Paine, J. P., American Pres. Lines, San Francisco, Calif.
Parker, C. C., Westinghouse Elec. Corp., Phoenix, Ariz.
Paulk, W. A., City of San Francisco, San Francisco, Calif.
Pellicano, J., Pacific Gas & Elec. Co., Oakland, Calif.
Prince, R. C., Bechtel Corp., San Francisco, Calif.
Scaroni, J. A., Jr., Pacific Tel. & Tel. Co., San Francisco, Calif.
Shank, H. C., Lockheed Aircraft, Burbank, Calif.
Soukup, E., The Tucson Gas, Elec. Light & Power Co., Tucson, Ariz.
Stobin, M. M., So. Calif. Gas Co., Los Angeles, Calif.
Swaim, J. V. (re-election), Trico Elec. Co-op., Tucson, Ariz.
Trautwein, R. T. (Student), Univ. of So. California, Los Angeles, Calif.
Wessa, A. P., California-Pacific Utilities Co., San Francisco, Calif.

9. North West

Amme, N. E., Bonneville Power Admin., Gold Bar, Wash.
Andersen, F. V., Bonneville Power Admin., Vancouver, Wash.
Anderson, E. W., Pacific Tel. & Tel. Co., Seattle, Wash.
Antosz, H. J., Bureau of Reclamation, Billings, Mont.
Barta, R. L., Bureau of Reclamation, Billings, Mont.
Beard, S. R., General Elec. Co., Salt Lake City, Utah
Button, J. R., General Elec. Co., Pasco, Wash.
Eastvedt, R. B., Bonneville Power Admin., Walla Walla, Wash.
Harbour, R. D., Washington State College, Pullman, Wash.
Hensen, W. C., Hensen Tele-Radio Co., Mountain Home, Idaho
Kearney, K. F., Eugene Water & Elec. Board, Eugene, Oreg.
Koehler, W. D., Corps of Engineer, U. S. Army, Portland, Oreg.
Nielsen, J. W., Geneva Steel Co., Salt Lake City, Utah
Thelen, F. S., General Elec. Co., Portland, Oreg.
Welch, R. L., U. S. Bureau of Reclamation, Billings, Mont.

10. Canada

Ashworth, H., Govt. of the Province of B. C., Vancouver, British Columbia, Canada
Brown, H. C., Canadian Westinghouse Co. Ltd., Ottawa, Ontario, Canada
Bulmer, H. O., British Columbia Elec. Rly. Co. Ltd., Vancouver, British Columbia, Canada
Coffer, W., Shawinigan Water & Power Co., La Gabelle, Quebec, Canada
Cook, L. H. J., B. C. Elec. Railway Co. Ltd., Vancouver, British Columbia, Canada
Duxbury, R. B., B. C. Elec. Co. Ltd., Vancouver, British Columbia, Canada
Evans, A. J., H. A. Simmons Consulting Engr., Vancouver, British Columbia, Canada
Goff, H. S. H., British Columbia Elec. Rly. Co. Ltd., Vancouver, British Columbia, Canada
Harris, W. J. H., Gypsum, Lime & Alabastine Co. Ltd., S. Westminster, British Columbia, Canada
MacLeod, D. N., C. P. R. Communications, Vancouver, British Columbia, Canada
Marsh, C., Canadian General Elec. Co. Ltd., Trois Rivieres, Quebec, Canada
Miles, W. F., British Columbia Elec. Rly. Co. Ltd., Vancouver, British Columbia, Canada
Mongrain, H. P., Technical School, Trois Rivieres, Quebec, Canada
Murchie, S., Brantford Township Hydro, Brantford, Ontario, Canada
Parker, J. O., Beauharnois Light, Heat & Power Co., Beauharnois, Quebec, Canada
Steele, D. J., Dominion Steel & Coal Corp., Ltd., Sydney, Nova Scotia, Canada
Stewart, R. C. A., Canadian General Elec. Co. Ltd., Vancouver, British Columbia, Canada
Swett, W. E., Bepco Canada Ltd., Westmount, Quebec, Canada
White, W. T., MacMillan Industries Ltd., Vancouver, British Columbia, Canada
Wilson, J. P., Dept. of Transport, Air Services Branch, Ottawa, Ontario, Canada

Elsewhere

Burge, H. C., Jr., Creole Petroleum Corp., Caripito, Venezuela, South America
da Cruz Barroso, A. C., Govt. of State of Rio de Janeiro, Brazil, South America
Evans, J. R., Creole Petroleum Corp., Maracaibo, Venezuela, South America
Garg, R. S., Hydro Elec. Works, Govt. of the United Provinces, Etah, United Provinces, India
Haines, P. J., South East London Tech. College, London, England
Narula, V. P., (Student), Indian Inst. of Science, Patiala, India
Rozycki, W., Bruce Peebles & Co. Ltd., Edinburgh, Scotland
Sarda, B. R., Solan Elec. Supply Co. Ltd., Solan, Simla Hills, India

Total to grade of Associate
United States, Canada, and Mexico, 290
Elsewhere, 8

IRE National Convention and Radio Show Held in New York

More than 16,000 persons attended the 1949 Institute of Radio Engineers' national convention and radio engineering show at the Hotel Commodore and the Grand Central Palace in New York, N. Y., March 7–11, 1949. Some 170 papers covering the entire range of radio engineering were presented and 225 exhibitors displayed over $6,000,000 worth of technical equipment during the convention.

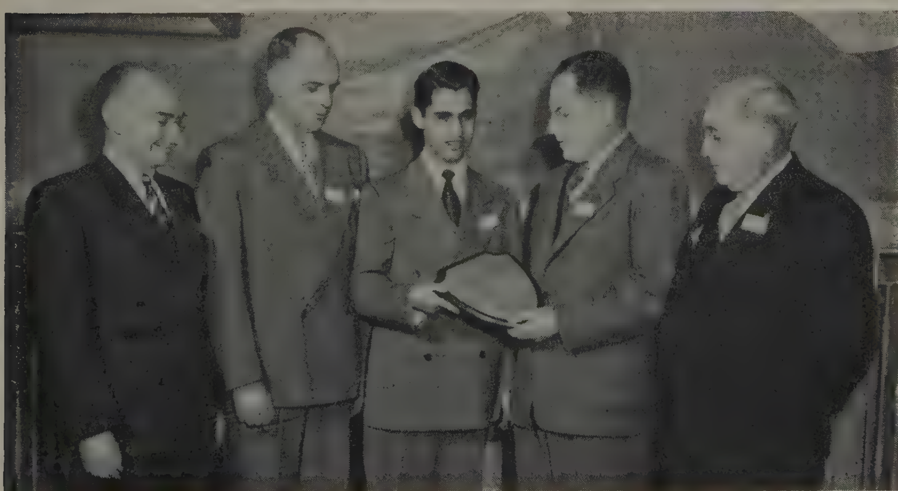
Technical papers presented included such subjects as modulation systems, antennas and waveguides, active and passive networks, instruments and measurements, audio systems, computers, components and materials, television, navigation aids, nuclear science, electronics, relay systems, semiconductors, information transmission and noise, oscillators, and marketing. The symposium on marketing, a new type of session for the Institute of Radio Engineers, included discussions on merchandising, developing new models, advertising, and sales promotion of radio and television receivers. Radio engineers were afforded a survey of how the products of the laboratories were introduced and sold to the public.

Stuart L. Bailey, new president of the Institute of Radio Engineers, was honored at the president's luncheon which was held on Tuesday, March 8, 1949. B. E. Shackelford, junior past president, acted as toastmaster at the luncheon, and D. W. Rentzel, Civil Aeronautics Administrator, principal speaker of the luncheon, spoke on "The Program for New Aids to Air Navigation." He cited the progress that had been made in this field, and outlined a program of air navigation and traffic control that will take place during the next 15 years. His talk included a demonstration (with the aid of animated diagrams) of new devices that will be coming into general air navigation use. These included omni-range, DME (distance measuring equipment), ILS (instrument landing system), and GCA (ground controlled approach).

Raymond F. Guy of the National Broadcasting Company was toastmaster at the 37th anniversary banquet which was held Wednesday evening, March 9, 1949. President Bailey addressed the gathering and presented a number of awards to distinguished members of the institute. The 1949 Medal of Honor was presented to Ralph Bown of Bell Telephone Laboratories "for his extensive contributions to the field of radio and for his leadership in institute affairs." C. E. Shannon of Bell Telephone Laboratories won the 1949 Morris Liebmann Memorial Prize "for his original and important contributions to the theory of the transmission of information in the presence of noise." The 1949 Browder J. Thompson Memorial Award went to R. V. Pound of Harvard University, "for his paper in the December 1947 *Proceedings of the I. R. E.* entitled 'Frequency Stabilization of Microwave Oscillators.'" Fellowship awards were presented to 31 outstanding members of the Institute of Radio Engineers, which included seven members of AIEE (see page 458 in this issue). Doctor Benjamin E. Shackelford, retiring president of the institute, reviewed briefly the institute's progress during his term in office. The principal speaker of the evening was Doctor Frank Stanton, president of Columbia Broadcasting System, Inc., whose topic was "Television and People." He discussed the social impact of this new entertainment medium, and cited some of its implications and problems.

The radio engineering show occupied three floors at the Grand Central Palace and featured all kinds of radio apparatus from recording equipment to radar exhibits. In addition to radio equipment manufacturers, the exhibitors included the United States Air Force, the United States Army Signal Corps, and the United States Navy, all of whom had large displays of the part radio engineering was playing in the various branches of the Armed Forces.

Illinois Tech Chapter Wins HKN Award



J. H. Kogen receives the Eta Kappa Nu Achievement Award for the academic year 1947–48 on behalf of the Delta chapter of the Illinois Institute of Technology, Chicago. The award is made annually to one of the society's 43 college chapters having the most outstanding "scholarship and activities" record. Participating in the presentation are the following Eta Kappa Nu officers (from left to right) E. T. B. Gross, (F'48) president of the Chicago alumni chapter and faculty adviser to the Delta chapter; L. A. Spangler, former national president; J. H. Kogen, (Student Member), president of the Delta chapter; F. E. Sanford (F'46—presenting the plaque), member of the national advisory board; and A. B. Zerby (A'38), executive secretary

New Equipment Speeds Long-Distance Calls

A new type of switching equipment, lately installed in New York and Chicago long distance centers, makes it possible for a long-distance operator to put through calls to distant telephones directly, without the aid of other operators en route. Already, about one-third of the long distance calls originating in New York City are being routed through the new equipment in the American Telephone and Telegraph's Long Lines Headquarters building.

Ultimately, the Bell System plans to extend this method, called operator toll dialing, throughout the United States and Canada. When this is done, an operator will be able to dial a number anywhere in the nation.

At the present time, operator toll-dialing networks enable operators to dial calls straight through to distant telephones in some 300 cities. Approximately ten per cent of the nation's long-distance calls now are being handled by this means. New automatic switching centers are scheduled to be established this year in Cleveland, Ohio, Oakland, Calif., and Boston, Mass., and in Albany, N. Y., in 1950.

The program for nation-wide toll dialing is based on the development of electronic devices which can select possible routes between distant cities, direct switching operations at intermediate points along a route, and complete connections automatically in a matter of seconds.

When the program is completed, long-dis-

tance calls will go through about twice as fast as they did in 1948. In addition to increasing the speed on calls requiring intermediate switching, toll dialing promises less difficulty from cut-offs and interruptions. Further, automatic selection of alternate routes by the new equipment will result in more efficient use of the telephone plant.

When toll dialing becomes nation-wide, the country will be divided into 80 areas, each being designated by a distinctive 3-digit code. Furthermore, each office within an area will possess a 3-digit office code. Thus, the operator will be able to complete any toll call by dialing a total of ten digits, the six digits of the area and office codes, and the four digits of the called telephone number.

In calling distant cities, the operator uses a 10-button key set, which works about twice as fast as an ordinary dial. Each time she punches a key, a tone pulse is sent out over the regular voice channels to the switching center. Each tone pulse is a combination of two different audible frequencies, which are classified and sorted out by the switching equipment.

Future Meetings of Other Societies

American Gas Association. Production and chemical conference. May 23–25, 1949, Hotel New Yorker, New York, N. Y.

American Gear Manufacturers Association. Annual meeting. June 6–8, 1949, The Homestead, Hot Springs, Va.

American Society of Mechanical Engineers. 1949 Spring meeting, May 2–4, 1949, New London, Conn. Semiannual meeting, June 27–30, 1949, San Francisco, Calif.

American Society for Quality Control—New England Quality Control Conference. Third annual meeting. May 5–6, 1949, Hotel Copley Plaza, Boston, Mass.

Electrochemical Society. Spring meeting. May 4–7, 1949, Benjamin Franklin Hotel, Philadelphia, Pa.

Engineering Foundation. June 16, 1949, Engineering Societies Building, New York, N. Y.

Instrument Society of America. Fourth annual Spring meeting. May 12–13, 1949, Royal York Hotel, Toronto, Ontario, Canada.

Michigan Safety Conference. 19th annual meeting. May 17–20, 1949, Hotels Leland, Shelvy, and Book-Cadillac, Detroit, Mich.

National Bureau of Standards. Two symposia on numerical analysis. Symposium I, June 24–25, 1949; Symposium II, June 27–29, 1949; (dates are tentative), Institute for Numerical Analysis, Los Angeles, Calif.

National District Heating Association. 40th annual meeting. May 24–27, 1949, The New Ocean House, Swampscott, Mass.

National Electrical Wholesalers Association. May 2–6, 1949, Netherland-Plaza Hotel, Cincinnati, Ohio.

National Fire Protection Association. May 16–19, 1949, Fairmont Hotel, San Francisco, Calif.

Society of Automotive Engineers. Summer meeting. June 5–10, 1949, French Lick Springs, French Lick, Ind.

Society for Experimental Stress Analysis. May 19–21, 1949, Statler Hotel, Detroit, Mich.

Vandenberg Approves USAF Regulation Establishing Broad Research Policy

General Hoyt S. Vandenberg, United States Air Force (USAF) Chief of Staff, has approved an Air Force regulation which establishes a broad policy foundation to be followed by all USAF organizations participating in the research and development program.

Air Force regulation 80–4, under consideration since early last summer, represents the combined opinions of Air Force research personnel and leading civilian scientific figures in the United States. It is the first USAF policy statement establishing comprehensive objectives in the conduct of Air Force research, which is defined as the "fundamental investigation of all activities where the discovery of applications of interest to the Air Force may be expected."

The regulation prescribes assignment of research directors with understanding of and sympathy for the problems of research and the research worker, authorship credit on scientific papers, increased research freedom on the part of the individual scientist, impartial methods of employment, and satisfactory working conditions. It also states that adequate housing and recreational facilities must be provided at research installations.

The broad policy statement was prepared under the guidance of the Director of Research and Development in the office of the Deputy Chief of Staff for Materiel, and was endorsed by the Scientific Advisory Board to the Chief of Staff, a USAF agency which evaluates and reports on the effects of scientific progress on military planning and operations.

The new regulation will govern all Air Force organizations engaged in applied, basic, or background research, and it clearly defines these three research fields.

Background research is the analysis of all knowledge available to insure that items of greatest military value are developed and that basic and applied research are guided into the most productive channels.

Basic research comprises fundamental studies to provide new factual knowledge which gives promise of contributing to new concepts, techniques, and materiel of value to the Air Force.

The ultimate aim of all USAF research activities is applied research, which is the application of scientific personnel, facilities, and knowledge to specific problems which arise from military requirements.

The three fields of research lead logically to a development program on specific instruments or weapons which give the greatest promise. The end result of an adequate research and development program is technical superiority of the Air Force.

The regulation points out that funds to support research activities must be allocated so that long-range research programs are possible. Budget estimates will support research in promising areas in addition to research for the solution of particular problems.

Efforts will be made to broaden the individual scientist's understanding of other research programs sponsored by the USAF. Assignment of scientists will be made to obtain the best possible utilization of each individual capability.

The regulation promises to augment the scientific effort available to the Air Force by liberalizing methods for hiring of consultants and for the letting of contracts and subcontracts for scientific research.

The new policy also calls for sponsoring research in universities and other nonprofit institutions, and the establishment of adequate facilities for research required within the Air Force. All research effort available in other government departments and agencies will be utilized to a maximum.

The regulation requires the Air Force to avoid breakdown of research into compartments so far as security will permit and promises maximum co-ordination between individuals and research organizations.

Air Force research is the responsibility of the Directorate of Research and Development, office of the Deputy Chief of Staff for Materiel. Broad research policies are co-ordinated with the Scientific Advisory Board. Development of equipment and materiel is assigned to Air Materiel Command with headquarters at Wright-Patterson Air Force Base, Dayton, Ohio.

Air Force research is divided into three main areas: materiel; human resources; and medical. Materiel research is conducted at the following Air Materiel Command installations: Wright-Patterson Air Force Base, Dayton, Ohio; Watson Laboratories, Red Bank, N. J.; Cambridge Field Station, Cambridge, Mass.; and Muroc Air Force Base, Palm Springs, Calif. Human resources research is conducted at: Headquarters, USAF, Washington, D. C.; Air University, Maxwell Air Force Base, Maxwell Field, Ala.; and Air Training Command, Barksdale Air Force Base, Shreveport, La. In the medical field, research is being conducted at the Air Force School of Aviation Medicine, Randolph Field, San Antonio, Tex.; Aero-Medical Laboratory, Wright-Patterson Air Force Base; and the Arctic Aero-Medical Laboratory, Ladd Field, Fairbanks, Alaska. Research for the Air Force is being conducted also by RAND, a nonprofit corporation located at Santa Monica, Calif., and by numerous universities, colleges, and civilian corporations throughout the United States.

Electrical Manufacturing Competition. The Gage Publishing Company, New York, N. Y., announces the 11th annual *Electrical Manufacturing* product-design-awards competition, five cash purses totaling $2,500 being offered for the most interesting and realistic accounts of new product developments. The competition is sponsored by the publishers to stimulate and encourage those engaged in the design and engineering of electrically operated products and to accord recognition for outstanding achievement. Certificates of award will be presented to successful contestants, and also to five companies designated by the jury of award for honorable mention. Entries now are being accepted. Closing date for the filing of manuscripts is June 30, 1949. Mail to *Electrical Manufacturing*, 1250 Avenue of the Americas, New York, N. Y. Winners will be announced in the 11th annual October product-design-awards issue of *Electrical Manufacturing*.

Queen of Bermuda's Electric Galley

The galley of the Queen of Bermuda, which is one of the most fully equipped electric installations of its kind afloat, contains island ranges, hot cupboards, fish fryers, salamanders, hot plates, water boilers, urns, and grillers. Completely refitted recently by the General Electric Company, Ltd., of England, the 16-year old ship uses electricity on a wide scale, ranging from propulsion and steering to lighting and ventilation. Two 7,500-kw turbo-alternators and four 4,750-horsepower a-c propulsion motors comprise the main propulsion equipment, the auxiliary machinery consisting of four 750-kw geared d-c turbo sets, 270 marine motors, and a plural starting system. Nearly 3/4 of a mile of tubing are used in the vessel's cold-cathode lighting system, one of the largest installations of this type to be used on shipboard

Libraries Call for Copies of Bound Engineering Indexes

Copies of the bound volumes of the Engineering Index from 1928 to date are needed by various libraries and organizations, both in the United States and abroad. There is a great demand for these volumes because they have become scarce and are out of print.

Those having these volumes available and not being used, should get in touch with Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th Street, New York 18, N. Y.

To Dedicate Illinois Electrical Building. The new $2,000,000 electrical engineering building of the University of Illinois, at Urbana, will be dedicated formally at ceremonies to be held May 19–21. Doctor W. L. Everitt, head of the electrical engineering department and recently appointed dean of the college of engineering, directed the planning of this building, which has ample facilities for experimental work in communications, illumination, measurements, servomechanisms, and electric machines. As an example, the machines laboratory covers an area of 12,400 square feet, and is equipped with sound proofing and forced-air ventilation. Electric transfer cables are provided to class and conference rooms throughout the building to facilitate lecture demonstrations. An important feature of the dedication ceremonies will be a symposium the main theme of which is "Expanding Frontiers in Electrical Engineering." Scientists from the campus and industry will discuss the following topics: electron and ion dynamics; semiconductors; statistical problems in electrical engineering; and applications in the fields of illumination, machines, and sound. Included in the ceremonies will be class reunion and guided tours through the electrical engineering building. Those interested in attending should register at the university at 9:00 a.m., Thursday, May 19. Hotel reservations can be made by writing Professor G. R. Peirce of the electrical engineering department.

Wilson Named NBS Section Chief. Bruce L. Wilson has been appointed chief of the engineering mechanics section of the National Bureau of Standards, Washington, D. C. In this capacity, he will direct research on structural elements and metal structures to determine their strength, deformation under load, and other mechanical properties, and will correlate the results with the theory of elastic behavior of materials. He also will conduct research on special apparatus and methods for measuring forces, deformations, and hardness, and methods for calibrating such equipment. Wilson has been in charge of experimental research to determine fatigue strength of screw threads of various thread forms for tests being made by the National Bureau of Standards in co-operation with the British National Physical Laboratory and the Canadian National Research Council. He has led in the development of large-capacity calibrating devices for use with testing machines for loads up to 10,000,000 pounds, and has engaged actively in the investigation of dynamometers, strain gauges, and methods of measuring hardness.

Chicago Lighting Manufacturers Organize. Chicago-area manufacturers of lighting equipment have formed a nonprofit organization, incorporated as the Chicago Lighting Equipment Manufacturers Association. The organization was formed for the purposes of representing its members before legislative groups, negotiating uniform labor contracts for its members and their employees and, in general, applying collective effort toward the solution of problems common to the industry. Officers of the corporation are: president, M. C. Wilt, Curtis Lighting, Inc.; vice-president, K. B. Lacy, Lighting Products, Inc.; secretary, L. K. Schoenbrod, Electro Manufacturing Corporation; treasurer, B. A. Mitchell, Mitchell Manufacturing Company. Directors are: M. C. Wilt; K. B. Lacy; L. K. Schoenbrod; Max Klein, All-Bright Electric Products Company; Louis Mided, Good Manufacturing Company; John Roberts, Universal Fluorescent Lighting Corporation; and Al Riskind, Harvstone Manufacturing Company. Following is a list of members: All-Bright Electric Products; Apex Metal Products; Curtis Lighting, Inc.; Esco Industries; Good Manufacturing Company; Grayco Products; Harvstone Manufacturing Company; House-O-Lite Corporation; Leader Electric Company; Lighting Products, Inc.; Lumalite Products Company; Mitchell Manufacturing Company; Solar Light Company; Universal Fluorescent Company; and Electro Manufacturing Corporation. Further information can be had by contacting V. R. Bohlman, Curtis Lighting, Inc., 6135 West 65th Street, Chicago 38, Ill.

1949 Electronics Conference Planned. Plans for the 1949 National Electronics Conference were made at the board of directors meeting held late last year at Chicago, Ill. It will be held at the Edgewater Beach Hotel in Chicago from September 26 to 28, 1949. Sponsoring the annual event will be the AIEE, the Institute of Radio Engineers, the Illinois Institute of Technology, the University of Illinois, and Northwestern University. This year's conference president will be G. H. Fett, professor of electrical engineering at the University of Illinois. A. W. Graf, Chicago patent attorney, will be the 1949 chairmen of the board of directors.

RCA Unveils Television Demonstrator. A "television dynamic demonstrator," a complete and operating 30-tube television receiver spread out on an upright panel to present a giant operating blueprint of the components and circuits of a television receiver, was displayed for the first time by the tube department of the Radio Corporation of America (RCA) at a special showing to the

radio and television trade press at the RCA Exhibition Hall in New York City. Resembling a giant operating schematic, the demonstrator has every component and circuit of a conventional home television receiver spread out on a $3^1/_2$ feet high by $5^1/_2$ feet wide panel and superimposed on a background circuit drawing. The demonstrator actually operates, reproducing sound and picture with the same definition, sensitivity, and stability as the well-known RCA Victor models *630TS* and *8TS30* whose essential circuits it utilizes. The signal is picked up with a conventional television antenna and high-quality images are presented on the face of a standard 10-inch kinescope also mounted on the panel. Composed of 200 plug-in parts, which permit the easy removal of the "demonstrators" components, the panel is arranged into ten functional sections. This permits step-by-step study of the radio-frequency section amplifier, the radio-frequency oscillator and converter, the sound intermediate-frequency amplifier, the audio amplifier and loud-speaker, the picture intermediate-frequency amplifier, video amplifier, synchronizing amplifier, vertical oscillator and deflection output, horizontal deflection and high voltage, horizontal oscillator and control, and power supply. Designed to train radio service men in television trouble-shooting techniques, the "television dynamic demonstrator" stems from previous "demonstrators," used during the war to speed up the teaching of electronics principles to war workers and armed services personnel.

Research on Electric Sparks. A $3,000 grant for research on phenomena associated with the behavior of electric sparks has been made available to the New York University college of engineering by The Research Corporation of New York City, Dean Thorndike Saville announced recently. The work will be supervised by Doctor Leon H. Fisher, assistant professor of physics at the college, and is a continuation of research which was inaugurated about a year ago as a faculty undertaking. The new grant will permit expedition of the project. The objective is to determine the time lag of spark discharges in air when under the influence of a uniform field and to relate this lag to atmospheric pressure and electrode separation. The principal apparatus used to date consists of a variable d-c power supply of 60,000 volts and an ionization chamber. Some preliminary orienting measurements have been made. When completed, the data obtained may aid in the design of electric equipment, particularly with respect to flash-over protection.

Savage Receives 1949 Washington Award. John L. Savage, consulting hydroelectric and irrigation engineer, has received the Washington Award for 1948. The award, established in 1916, is presented annually by the Washington Award Commission to the engineer "whose services have been noteworthy in promoting the public good."

Rinehart Named RDB Secretary. Doctor Robert Fross Rinehart has been appointed executive secretary of the Research and Development Board. Doctor Rinehart, who has been associated with the board as director of its planning division since July 1948, assumed his new duties on February 1, 1949. He replaced Doctor Lawrence R. Hafstad who resigned from the board to accept the post of director of reactor development division, Atomic Energy Commission.

RESA Gets New Officers. Donald B. Prentice, formerly president of Rose Polytechnic Institute, is the new full-time director of the Scientific Research Society of America (RESA). Other recently elected officers are: Doctor George A. Stetson, editor of publications of the American Society of Mechanical Engineers, chairman; and Doctor George A. Baitsell, Colgate professor of biology at Yale University, treasurer. RESA was founded in 1947 to provide a closer association between university scientists and their colleagues in industrial and government laboratories. This national organization, which has headquarters at Yale, is an offspring of Sigma Xi. RESA also elected the following men to the board of governors: Doctor Joseph W. Barker, president of the Research Corporation, of New York City; President W. V. Houston, Rice Institute, Houston, Tex.; Doctor M. C. K. Jones, Esso Research Laboratories, Elizabeth, N. J.; Doctor William Procter, Palm Beach, Fla.; Doctor Stetson; Doctor C. G. Suits, director of the research laboratory of the General Electric Company, Schenectady, N. Y.; Doctor C. A. Thomas, executive vice-president of the Monsanto Chemical Company, St. Louis, Mo.; Doctor William E. Vaughan, director of research for the Shell Development Company, Emeryville, Calif.; and Doctor Edward R. Weidlein, director of the Mellon Institute of Pittsburgh, Pa. Three members of the board of governors, ex officio, are: Doctor Carl D. Anderson, president of Sigma Xi; Doctor Baitsell; and Doctor George B. Pegram, treasurer of Sigma Xi.

ECPD Suggests Engineering Societies Standardize Membership Grades

Though final action has not been taken as yet, the committee on professional recognition of the Engineers' Council for Professional Development is well on the way to agreement on a recommendation to national engineering societies that membership grades and minimum qualifications for membership be standardized. Three essential grades of membership are contemplated: Member, Associate Member, and Student Member, with two other grades suggested for those societies that may wish to adopt them: Fellow, and Affiliate.

A Member shall have had an engineering degree, with at least four years of increasingly important engineering experience indicative of growth in engineering competency and achievement, at least two years of which, he shall have been in responsible charge of engineering work. Or, if not a graduate, he shall have had at least ten years of engineering experience satisfactory to the society. A license to practice professional engineering or the passing of an examination prescribed by the governing board of the engineering society involved, may be accepted as qualifying experience. Teaching also may be considered as qualifying experience. If not an engineering graduate, graduation from a natural- or physical-science curriculum may be acceptable, though such training preferably should qualify a man for Associate Membership.

An Associate Member shall be merely a graduate of an engineering or physical-science curriculum, with no experience required; or, if not a graduate, he should have had at least six years of professional experience.

A Student Member shall be an undergraduate or graduate engineering student in the professional field of the society.

A Fellow is purely an honorary grade, for engineers of distinction for which the member makes no application.

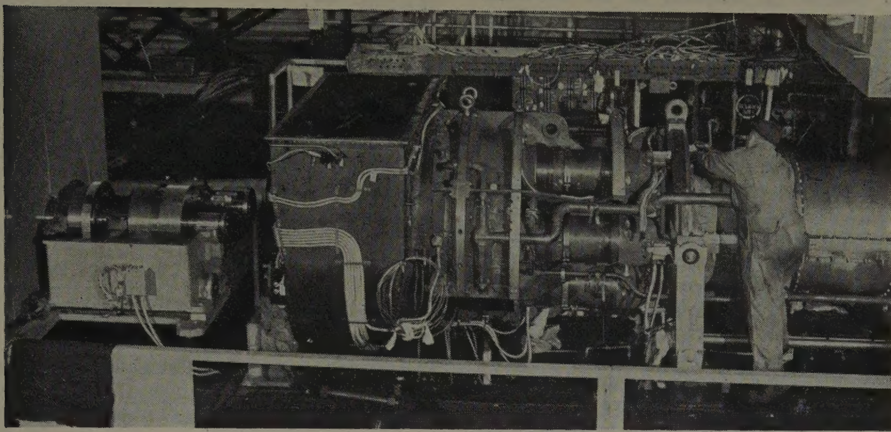
The Affiliate grade would apply to those who are not professional engineers, but who co-operate with engineers in the advancement of engineering knowledge and practice.

Comment on the foregoing suggestions is invited by the secretary of Engineers' Council for Professional Development, 14th floor, 29 West 39th Street, New York 18, N. Y. A final meeting of the committee to discuss the subject is planned for late May.

Westinghouse Names Nuclear Manager. The Westinghouse Research Laboratories, Pittsburgh, Pa., have appointed Doctor John W. Coltman, former head of the laboratories' X-ray section, as manager of the electronics and nuclear physics department. Coltman joined Westinghouse Laboratories in 1941, and gained national recognition in 1948 for his development of the X-ray "telescope" that provides a 500-times brighter image for X-ray fluoroscopic screens. He also supervised the design of air-pressure and water-pressure instrumentation at the Bikini atom-bomb tests.

M. J. Dooher, New AMA Editor. The American Management Association (AMA) has appointed M. J. Dooher as editor of the association. He succeeds James O. Rice, former editor, recently elected secretary of the national management group. Dooher will be in charge of the editing and publishing of the association's magazine, *Personnel*, for industrial relations executives and personnel administrators, and *The Management Review*, monthly digest of current business reading. He also will have charge of publication of the proceedings of AMA's 11 annual conferences of executives in the fields of industrial relations, marketing, production, finance, packaging, insurance, and office administration. In addition, he will direct AMA's "Personnel Workshop," a semi-annual exhibit of 10,000 pieces of selected employee and supervisory literature in current use in American business. Dooher joined the AMA in 1937 as assistant editor. Since then he has been associate editor and then managing editor of the organization's publications.

Combustion Gas Turbine Power Plant



The first combustion gas turbine power plant to be built and sold in the United States for central-station use is shown on test at the General Electric Company plant in Schenectady, N. Y. The unit, rated 3,500 kw, will be utilized by the Oklahoma Gas and Electric Company for the generation of electricity

IRE to Discuss Aviation Radio at Dayton. The Dayton section of the Institute of Radio Engineers is planning a series of annual technical conferences, the first of which will be held June 3 and 4, 1949, at the Biltmore Hotel, Dayton, Ohio. The keynote of the first conference will be "Development and Future Trends in Air-borne Electronics." Besides the technical program, there will be displays and exhibits from various manufacturers in the electronic field. Arrangements have been made for a visit to the laboratories of the Engineering Division of Air Materiel Command at Wright-Patterson Air Force Base. At the sessions, papers will be presented by top men in their respective fields. Discussions on the following general subjects are scheduled: aircraft communications equipment and theory; air navigation and traffic control systems; antenna developments for high-speed aircraft; air-to-air radio-frequency propagation; design trends in air-borne electronic systems; and physiological aspects in the design of air-borne electronic equipment. Doctor W. L. Everitt, dean of engineering at the University of Illinois, will be toastmaster at a banquet to be held on June 3, 1949. The principal speaker tentatively is scheduled to be W. Stuart Symington, Secretary of the Air Force.

AEC Reactor Development Head. The United States Atomic Energy Commission has named Doctor Lawrence R. Hafstad, executive secretary of the Joint Research and Development Board, National Military Establishment, as director of the Reactor Development Division of the Commission. Created in 1948, this division is to carry out the program of designing and developing nuclear reactors for practical application of atomic power for power, for propulsion of ships and aircraft, for production of isotopes, and for research on reactors themselves. Doctor Hafstad was formerly director of research, applied physics laboratory, Johns Hopkins University, Silver Springs, Md.

New Officers for Welding Association. B. L. Wise, director of production, National Electric Welding Machines Company, Bay City, Mich., has been elected president of the Resistance Welder Manufacturers' Association at the association's annual meeting in Detroit. He succeeds T. S. Long, vice-president and general manager, Taylor-Winfield Corporation, Warren, Ohio, who was elected chairman of the executive committee. Named vice-president of the group, which comprises manufacturers of resistance welding equipment, was T. Embury Jones, president, Precision Welder and Machine Company, Cincinnati, Ohio. The "alloy" group in the association, comprising manufacturers of resistance welding electrodes, and so on, elected as its chairman, W. G. Fetter, manager, resistance welding division, P. R. Mallory and Company, Inc., Indianapolis, Ind. George A. Fernley and H. R. Rinehart were re-elected executive secretary and secretary-treasurer, respectively. Fernley and Rinehart make their headquarters at the association's main offices at 505 Arch Street, Philadelphia, Pa.

Piper Appointed to NBS. W. M. Piper has been appointed to the staff of the National Bureau of Standards, where he will do research in the ordnance mechanics laboratory of the electronics division. Piper has designed and built electronic test equipment, including wide-range video amplifiers, and high-fidelity public address systems. From 1945 to 1948 he was a project engineer in charge of research and development of all batteries and related equipment for the Office of Chief Signal Officer, Department of the Army. From 1942 to 1945 he conducted engineering studies for the distribution of power from Grand Coulee and Bonneville Dams under the United States Department of the Interior and from 1936 to 1942 acted as a part-time radio consultant, experimenting with public-address and other electronic installations.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

Electrical Essays

To the Editor:

In his letter to the editor (*EE, Feb '49, p 186*), A. A. Kroneberg takes me somewhat to task for the solution which I gave (*EE, Dec '48, p 1141*) to my electrical essay, "4-Terminal Network" (*EE, Nov '48, p 1073*). There is no question that what I gave was a solution, but there is an implication of being let down, an implication that perhaps my answer was not fair. Kroneberg well might ask me why, since in my answer I made essential use of only four transformers, did I in my question mention six transformers.

The answer is, of course, that I did this to mislead, and make the problem hard. I thought that on seeing the various equilateral triangles making the four faces of the apparently analogous tetrahedron of matches, the gullible reader would spend some time futilely trying to arrange 3-phase electric systems of a single frequency into a similar electrical tetrahedron, before discovering that more than one frequency is necessary.

Kroneberg apparently saw through my attempted deception and realized that he would need more than one frequency, but because I mentioned six transformers, he felt challenged really to use six transformers, even though four would be enough. He then gives a circuit which purports to do this.

I tried to check the circuit he gave in his

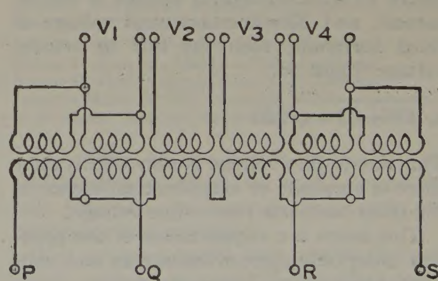


Figure 1. Connections suggested by A. A. Kroneberg in his letter to the editor published in the February issue

letter, but apparently there is some error in the specification of the voltages which he applies to his transformers. Numbering the transformers in his diagram *1* to *6*, from left to right, and keeping his secondary connections the same, I find that if I call the primary voltages, E_1 to E_6, I must make $E_3 = -E_4$ to get the required equal rms voltage the same for any pair of the terminals *P*, *Q*, *R*, and *S*. E_1, E_2, E_5, and E_6 all should be equal in rms value, and each should differ from each of the other three either by 90 degrees in phase, or in frequency. I am not sure that Kroneberg will be satisfied with this manner of making use of transformers *3* and *4*.

Kroneberg brings out a good point in indicating that no more than two frequencies are ever necessary for solving problems of this type. I did not need the four frequencies as used in my solution.

That two frequencies always will suffice first was brought to my attention by Stanley R. Jordan of Dayton, Ohio. Jordan put three transformers in a 3-phase Y, with equal balanced 3-phase single-frequency voltages from transformer Y terminals, *P*, *Q*, *R*, to neutral, *O*. Jordan then connected his fourth transformer from neutral *O* to the fourth point *Q*, and excited it at another frequency and with an amplitude 1.414 times the amplitude of each of the other voltages. Jordan failed to tell me what he did with the remaining two transformers.

J. SLEPIAN (F '27)

(Associate director, Westinghouse Research Laboratories, East Pittsburgh, Pa.)

To the Editor:

This is in reference to the electrical essay published in the November issue (*EE, Nov '48, p 1073*).

I would like to suggest a solution different from the one offered by Doctor Slepian in the December issue (*EE, Dec '48, p 1141*) and which, I believe, would be more in line with a power engineer's thinking. The solution follows.

Three transformers are connected in a 3-phase Y system with neutral return to the voltage source. Label the secondary line terminals *P*, *Q*, and *R*, and the neutral *S*. Now if the voltage impressed on the primary has a third harmonic of magnitude such that

$$\sqrt{E1^2+E3^2}=\sqrt{3}E1$$

or

$$E3=\sqrt{2}E1$$

where $E1$ = line-to-neutral voltage of fundamental, and $E3$ = line-to-neutral voltage of third harmonic, then the line to neutral voltage would be

$$\sqrt{E1^2+E3}=\sqrt{3}E1$$

The line-to-line voltage is also $\sqrt{3}E1$, since there is no phase or amplitude difference in the third harmonic line-to-line voltage.

This meets the requirements of the problem using only three transformers and voltages of two different frequencies.

JACK RUINA

(Research Fellow, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

To the Editor:

I submit that the so-called "solution" of the essayist (J. Slepian) to the electrical essay for November 1948 (*EE, Nov '48, p 1073*) is wrong. This solution was published in the December issue (*EE, Dec '48, p 1141*).

My solution is the following. Connect the six secondaries to the four points *PQRS* in the manner of the six arms of a wheatstone bridge (that is, the four so-called "bridge arms" plus the generator and galvanometer arms). Energize each primary at a different frequency supplied from a sine-wave generator of impedance suitable to give the same impedance at each frequency when looking back into each secondary and to give the same open circuit voltage in each secondary when disconnected from *PQRS*.

Consider the effect of one generator, making for the moment the voltages of the other generators all zero. The first generator will deliver a certain power *W* into each of the four equal adjacent arms and no power into the conjugate or galvanometer arm. A power 4*W* will be dissipated in the impedance which is seen looking back into the secondary in question. By the superposition principle these powers will remain unchanged as the voltages of the remaining generators each are raised in turn from zero to the specified value. When all six primaries are energized, each secondary is a generator arm for one frequency, a neighboring or bridge arm for four frequencies, and a conjugate or galvanometer arm for one frequency. The total power appearing in any one arm is therefore 8*W*. Since the frequencies of the five contributions to each total power are different, no generator is short-circuited and the rms voltages are all the same.

My solution requires all six primaries to be energized rather than merely four primaries as the essayist proposes. Furthermore, I dispute that his "solution" even agrees in terms with his statement of the problem. He does not connect his secondaries to the four points *PQRS*, but to five points.

J. C. STEWART

(Carrier telephone design, Redbourn Pty. Limited, Sydney, Australia)

Exponential Rise

To the Editor:

In 1933, L. A. Doggett[1] indicated that an exponential rise curve can be plotted as a straight line on a graph where semilog paper is used with an upside-down logarithmic ordinate scale. To my knowledge this useful scheme is not generally known, nor has the proof ever been published.

The type of function to be graphed may be represented:

$$F=A(1-e^{-t/b})$$

where *b* is the time constant. This is typified by the rise of current in an inductive circuit, or the rise of voltage in charging a capacitor through a resistor. It is most convenient in graphing this function using this scheme if *A* is taken as 100 units and *F* is described in percentage of *A*.

$$F=100-100e^{-t/b}$$

or

$$100-F=100e^{-t/b}$$

Let some number *M* be defined as $100-F$. Then

$$M=100e^{-t/b}$$

$$\log_c M=\log_c 100-\frac{t}{b}\log_c e$$

Now suppose a graph paper is available in which the *Y* distance, or ordinate, is equal to $\log_c N$, but in a negative direction. This is obtained by turning ordinary semilog graph paper upside-down.

$$y=-\log_c M$$

$$y=-\log_c 100+\frac{\log_c e}{b}t$$

This is the equation of a straight line, the slope of which is $\frac{\log_c e}{b}$, or, if common logarithms are used,

$$\text{slope}=1/2.303\ b$$

The *y* intercept is at $-\log_c 100$. If the graph be labeled in units of *F* instead of units of *y* or *N*, this point corresponds to $F=0$. See Figure 1.

One of the most valuable uses of such a plot would be to show where the parameters

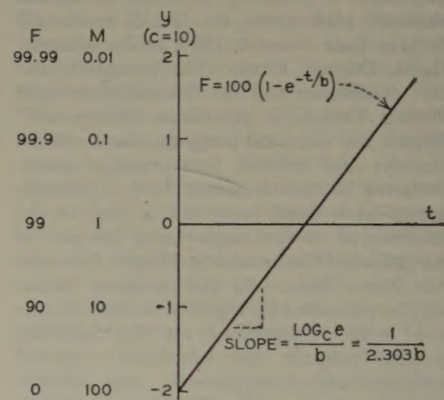


Figure 1. Exponential rise function plotted as straight line

of a circuit change value. For example, as the current in an inductance increases, we might expect to see the slope of the graph increase corresponding to a decreasing inductance.

REFERENCE

1. **L. A. Doggett.** *Journal of Engineering Education* (Lancaster, Pa.), volume 23, pages 695–8.

CHARLES R. AMMERMAN

(Instructor of electrical engineering, The Pennsylvania State College, State College, Pa.)

Partial Fraction Expansion

To the Editor:

An interesting procedure in partial fraction expansion of a complex admittance as used in operational mathematics has come to the writer's attention. It may be applied to either the Heaviside method or the Laplace transform method.

When evaluation of complex roots is encountered, determination of the coeffi-

cients in such a form as to give the result as

$$B \cos \omega rt + \frac{C}{\beta} \sin \omega rt$$

directly is desirable. Such a method can be set up.

Basing on the expression,

$$\frac{M(s)}{D(s)} = \sum_{j=1}^{n} \frac{A_j}{s-s_j}$$

one common method of evaluating A_j is

$$A_j = \left.\frac{M(s)(s-s_j)}{D(s)}\right|_{s=s_j}$$

This method may be used for s_j complex, but does not give coefficients in the desired form. If A_j is set up in the following manner, it can be shown that the coefficients take the desired form.

Take

$$S_j = -\alpha + j\beta D(s) = f(s)[(s+\alpha)^2+\beta^2]$$

$$A_j = \left.\frac{Ms[(s+\alpha)^2+\beta^2]}{Ds}\right|_{s_j} = \left.\frac{M(s)}{f(s)}\right|_{s_j}$$

For this equation,

$$A_j = \frac{M(-\alpha+j\beta)f^*(-\alpha+j\beta)}{f(-\alpha+j\beta)f^*(-\alpha+j\beta)}$$

where f^* is the conjugate of f, and so forth.

To evaluate and prove this to be possible, take

$$\frac{M(s)}{D(s)} = \frac{A}{f(s)} + \frac{B(s+\alpha)}{[(s+\alpha)^2+\beta^2]} + \frac{C}{(s+\alpha)^2+\beta^2}$$

$$\therefore M(s) = A[(s+\alpha)^2+\beta^2[+B(s+\alpha)f(s)+Cf(s)$$

$$B(s+\alpha)f(s)+Cf(s)|_{s=-\alpha+j\beta} = M(s)|_{s=-\alpha+j\beta}$$

$$\therefore B(j\beta)f(-\alpha+j\beta)+Cf(-\alpha+j\beta) = M(-\alpha+j\beta)$$

Taking real and imaginary parts,

$$-B\beta I(f)+CR(f) = R(M)$$
$$B\beta R(f)+CI(f) = I(M)$$

Solving for B and C,

$$B = \frac{\begin{vmatrix} R(M) & R(f) \\ I(M) & I(f) \end{vmatrix}}{\begin{vmatrix} -\beta I(f) & R(f) \\ -\beta R(f) & I(f) \end{vmatrix}} = \frac{R(M)I(f)-I(M)R(f)}{-\beta(I^2(f)+R^2(f))}$$

$$C = \frac{-\beta I(M)I(f)-\beta R(M)R(f)}{-\beta(R^2(f)+I^2(f))} = \frac{I(M)I(f)+R(M)R(f)}{R^2(f)+I^2(f)}$$

But

$$A_j = \frac{R(M)R(f)+I(M)I(f)}{R^2(f)+I^2(f)} + j\frac{I(M)R(f)-R(M)I(f)}{R^2(f)+I^2(f)}$$

But B is the coefficient of $\epsilon^{-\alpha t} \cos \beta t$, and the imaginary part of $A_j = \beta B$, C is the coefficient of $\frac{1}{\beta}\epsilon^{-\alpha t} \sin \beta t$, and the real part of $A_j = C$. Hence this substitution yields directly the coefficients of the sine and cosine terms.

KEATS A. PULLEN, JR. (A '42)
(Ballistic Research Laboratories, Aberdeen Proving Ground, Md.)

Reverse Blowout Effect

To the Editor:

The article "The Reverse Blowout Effect," by G. J. Himler and G. I. Cohn,[1] contains an interesting theory of this well-known phenomenon,[2–8] but there are several questionable points which should not be accepted without further examination. In the first place, electrons are assumed to leave the cathode with velocities randomly distributed in direction, with this directional spread determining the effect of the magnetic field on the individual electrons. However, it is most likely that practically all the electrons leave the cathode along the normal to the surface, especially if the emission is due to either a thermionic or a field effect. Admittedly, it is difficult to discuss the directional distribution of initial velocities when the emission mechanism is not clearly understood. As we have pointed out in a recent article,[9] none of the theories of the so-called "cold" arc are completely in accord with all the facts.

The curves showing the effect of magnetic field on the pressure at reversal seem to be at variance with our observations[6] since we have found that the reversing pressure increases linearly with increasing magnetic field at constant arc current. At constant magnetic field, the reversing pressure decreases with increasing arc current. Reversing pressures in various gases (He, A, N_2, H_2, O_2, CO_2, and Hg) ranged from 0.2 centimeter to 60 centimeters Hg with magnetic fields ranging from 10 to 450 gauss, and currents from 2 to 10 amperes. In general, gases with higher resonance potentials have higher reversing pressures.

A further difficulty with the theory given by Himler and Cohn is that the length of the cycloidal trajectory for even the smallest probable electric field (10^4 volts per centimeter) would be several hundred times the mean free path at the lowest observed pressures. As they correctly state, the deviation from the normal path would be very small at atmospheric pressure, but would not be appreciably greater even at the lower pressures.

We agree with the authors that whatever is causing the reverse motion must be intimately associated with the surface and the region immediately above it. However, we have observed the effect to exist with many kinds of metal electrodes and never have found that the phenomenon was sensitive to the type of surface. Smith[8] and the undersigned have observed independently that the reverse motion does not take place on cathodes which are at sufficiently high temperatures to sustain the arc by thermionic emission. Smith observed this effect on tantalum and we have found it for tungsten.

We feel that none of the theories advanced to explain this phenomenon are completely satisfactory. We hope that this article and discussion will stimulate interest in this fascinating problem which eventually will lead to the true explanation.

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Report From Korea

To the Editor:

I suppose a few of your readers would like to know what I am doing here in the Far East. I was appointed chief of the Korean Power Mission to assist the Koreans and instruct them in the operations of their power plants here in South Korea. They have three utility steam plants and about five small hydroelectric plants with plans for about 30 future hydro units.

The largest of the steam plants is at Yong Wal. It has an installed capacity of 100,000 kw but so far due to bad coal never has sustained more than 3,500 kw for any length of time. It is the mission of this group to see if we can get this plant to come more up to rated capacity. This plant's fuel comes from what we in the United States would call a captive mine about eight miles distant across the mountains. The coal is transported by cable way from mine to powerhouse. The coal they are forced to burn at this plant we would throw on the ash pile—42 to 52 per cent ash semianthracite. The other two steam plants are smaller in capacity but here again there is coal trouble as well as lack of operations. You see, all these plants were standby units for winter or dry weather operations.

For the benefit of the readers of *ELECTRICAL ENGINEERING*, it might be well to list the membership of the Korean Power Mission, some of whom are members of AIEE and all who probably will be known by other members.

Loyal R. Milburn (F '39), consulting electrical engineer, Detroit, Mich., Chief of Mission
Edwin B. Rall, former assistant superintendent, Connus Creek plant, Detroit Edison Company
John A. Clay, West Colorado Power Company
George B. Foss, Sr., Alabama Power Company
Roscoe D. Hart, Central Illinois Light Company
Leslie O. Heath (M '23), Leeds and Northrup Company
C. H. Rhudy, Southern California Power Company

Over here we are known as the "Seven Old Men" and believe me, after a 30- or 40-mile Jeep ride over some of these roads, we do feel our age very much.

The one big problem here is to teach these people without trying to change them from oriental to western. There are several good engineers here and they also produce some very good mechanics, however they will need more time to produce sufficient personnel to

keep their plants running at top efficiency. Each of the three power companies have attached to this mission a young engineer who works with our group. We, in turn, try to teach these men what little we know so that when we leave this republic there will be seven or eight young engineers that will know somewhat more then than they now do about power generations, boiler room practice, and distribution.

One of the big handicaps is the lack of operating meters. These we will try to adjust with the help of the test meters we have coming. Once their meters are tested, repaired, and put into first class condition, we feel sure that the combustion, operation, and distribution will improve.

LOYAL R. MILBURN (F'39)

(Chief, Korean Power Commission, Seoul, Korea)

Dimensions of Resistivity

Editor's Note: In response to many letters received in reference to the letter to the editor by J. A. Williams, November issue of *ELECTRICAL ENGINEERING* (*p 1129*) and the letter by William E. Warden in the January issue (*p 92*), *ELECTRICAL ENGINEERING* has solicited the following letter in a attempt to avoid misunderstandings of the subject. This letter gives a definition of resistivity.

To the Editor:

Resistivity is defined as the resistance between opposite faces of a cube of unit dimensions. In the c.g.s. system this becomes ohms for a centimeter cube. For a long time this was abbreviated to ohms per cm^3, sometimes written ohm/cm^3 or ohm-cm^3. No division or multiplication was implied and the centimeter cube was not intended to be c.c. or it would have been written that way. This form of abbreviation caused considerable confusion. It is not correct dimensionally and has now been almost entirely discarded in favor of ohm-cm which is dimensionally correct and is equally so in any other system such as the M K S system where it would be ohm-m. However it does not in itself furnish an adequate definition of resistivity.

Another unit is in popular use, the resistance of a length of one foot having an area of one circular mil. It is open to question whether this should be considered a unit of resistivity at all, because none of the three units involved belong in the same system and the units of length and area are not even commensurate. It is a purely arbitrary unit, but still a very popular and useful one. Like the ohm per centimeter cube it has been abbreviated to ohm per circular mil foot, as a descriptive abbreviation, no multiplication or division being implied. When abbreviated to ohm/mil foot it is obviously incorrect dimensionally and no mathematics will make it correct. The only two solutions are to take it as a descriptive term and forget about the dimensions or educate the user to the term ohm-circular mil/ft which has the advantage of being not only dimensionally correct, but is in itself a complete definition of resistivity in terms of this arbitary unit.

J. G. FERGUSON (M'29)
(Transmission measurement engineer, Bell Telephone Laboratories, New York, NY.)

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

SPECIFICATIONS AND LAW ON ENGINEERING WORKS. By W. C. Sadler. John Wiley and Sons, New York, N. Y.; Chapman and Hall, Ltd., London, England, 1948. 493 pages, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $5. A foundation in engineering law for the writing of specifications. A summary of the historical significance of various legal systems is included. Among the topics specifically discussed with examples taken from actual experience are the legal instruments of contractual documents, illegal matters of concern to engineers, the law on agency partnerships and corporations, patents, and workmen's compensation.

SUPERSONICS, THE SCIENCE OF INAUDIBLE SOUNDS. (The Charles K. Colver Lectures 1937). By R. W. Wood. Brown University, Providence, R. I., 1939, reprinted 1948. 162 pages, illustrations, diagrams, charts, tables, $7^3/_4$ by 5 inches, cloth, $2. This small volume, originally published in 1939, has been reprinted with an additional bibliography of 48 items from the period 1936–47. The text covers the history of supersonics, mechanical and electrical sources of inaudible sound, and the physical and biological effects of high-frequency sound waves.

THEORY AND PRACTICE OF HEAT ENGINES. By V. M. Faires. Macmillan Company, New York, N. Y., 1948. 388 pages, illustrations, diagrams, charts, tables, $9^1/_2$ by 6 inches, cloth, $5. This text is designed primarily for students taking a terminal course in heat power. The customary descriptive matter on engines, turbines, compressors, and steam generators is accompanied by an appraisal of the appropriate theoretical developments. Emphasis is placed throughout the book on the application of the law of conservation of energy by the recurrent use of the general energy equation.

VELOCITY-MODULATED THERMIONIC TUBES. By A. H. W. Beck. Macmillan Company, New York, N. Y.; University Press, Cambridge, England, 1948. 180 pages, diagrams, tables, $8^1/_2$ by $5^1/_2$ inches, cloth, $3.75 (15s. abroad). Readily intelligible to anyone with a reasonably adequate knowledge of pre-1939 radio technique, this book gives a general introduction to velocity-modulation tubes and their mode of operation. The major part is devoted to the general theory of the interchange of energy between field and beam and the applications of this theory to various types of velocity-modulated tubes.

HOW TO SOLVE PROBLEMS IN STEAM POWER ENGINEERING. By S. J. Tracy, Jr. Thomas Y. Crowell Company, New York, N. Y., 1948. 152 pages, diagrams, charts, tables, $8^1/_2$ by $5^1/_2$ inches, paper, $1.25. A comprehensive collection of problems embracing the application of all the basic principles of steam power theory. Step-by-step solutions for each phase of the subject are given. In each chapter the problems have been arranged to provide a logical sequence in the analysis and development of the major topics.

JET PROPULSION IN COMMERCIAL AIR TRANSPORTATION. By R. E. Hage. Princeton University Press, Princeton, N. J., 1948. 91 pages, diagrams, charts, maps, tables, 9 by $6^1/_4$ inches, paper, $1.50. In dealing with this outstanding question, the author discusses the evolution of speed and its effect on commercial transportation, basic power-plant and aerodynamic characteristics, and the case for the turbojet commercial transport.

Library Services

ENGINEERING Societies Library books may be borrowed by mail by AIEE members for a small handling charge. The library also prepares bibliographies, maintains search and photostat services, and can provide microfilm copies of any item in its collection. Address inquiries to Ralph H. Phelps, Director, Engineering Societies Library, 29 West 39th St., New York 18, N. Y.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

Prevention of Deterioration Abstracts. 2,000 pages to be published per year, loose leaf style. Two binders and index guides will be furnished. Abstracts of journal articles, patents, and unpublished reports on all phases of deterioration from university, government, and industrial research groups, domestic and foreign, will be used. Yearly subscription prior to July 1, 1949, will be $37.50; after that date, $50. The National Research Council, Prevention of Deterioration Center, Room 204, 2101 Constitution Avenue, Washington, D. C.

Research Accrediting at the Naval Research Laboratory. A bulletin covering all phases of the accrediting program, including a list of courses and instructors. Available upon request to the Naval Research Laboratory, Washington, D. C.

Report on Fluorine Corrosion. A 4-page report on high-temperature attacks on metals and resistances to fluorine and fluorides, with charts and a table of rates of corrosive attacks. Available from The International Nickel Company, Inc., 67 Wall Street, New York, N. Y.

Classroom Radio Receivers. A guide to teachers and school administrators in the purchase and utilization of radios for classrooms. Available without charge from the Radio Section, United States Office of Education, Washington 25, D. C.

Increasing Productivity in Factory and Office. A check list of 61 studies providing information on increasing productivity for production executives, personnel directors, and office managers. Available upon request from the American Management Association, 330 West 42d Street, New York 18, N. Y.

Material and Methods Manual 35, Aluminum Alloy Castings. Discusses the various alloys and both the advantages and disadvantages of different casting methods and design limitations. Available upon request.

Nuclear Charts. Set of six lithographed wall charts in two colors illustrating the important areas of nuclear physics and accompanied by a 32-page booklet of supplementary information. Price per set $1 from School Service, Westinghouse Electric Corporation, Pittsburgh, Pa.

An Analysis of the Real Cost of TVA Power. A report and analysis of the financial aspects of the expanding Tennessee Valley project. Available from the Chamber of Commerce of the United States, Washington, D. C.